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Research Review

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Alternative methods of seed potato (*Solanum tuberosum*) production: Indian perspective — a review

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ABSTRACT

Quality seed is a major and important input in potato cultivation. Due to vegetative propagation in potato, requirement of seed potato tubers is voluminous, accounting for 50 to 70% of the total cost of potato production. The productivity of potato in many countries is low, primarily due to either non-availability or inadequacy of quality seed potato. The alternative methods of seed potato production will not only help in bridging the gaps in demand but also assist in overcoming the problems that are inherently associated with the conventional multiplication system of potato. The information are meagre on these aspects.Therefore, an overview on seed potato and potato seed production via different alternative methods namely tuber sprout technique, synthetic seeds, true potato seeds, micro-propagation, bioreactor technology, hydroponic system, aeroponic system, techni-tubers, apical rooted cuttings, little tubers and utilization of under-sized tubers (left in the field) is presented. Different aspects like, present scenario, significance, feasibility and practicability are being covered. Efforts that have been made to achieve a balance between use of quality seed potatoes via conventional and different alternative methods togethigher production and productivity of potato are covered here. Issues of higher occupancy of potato in cold storage space due to storage of conventional seed potatoes and how this can be reduced by enhancing the use of alternative methods with more effective and diversified utilization of cold storage space are also discussed.

Key Words: Aeroponics, Bio-reactor technology, Cold storage space, Hydroponics, Little-tubers, Micropropagation, Mini-tubers, Seed potato, Synthetic seeds

In one of the innovative experiments conducted at the International Potato Centre (CIP) along with NASA and scientists and engineers from the University of Engineering and Technology (UTEC) in Lima, potato has been found to be suitable for its cultivation on the planet Mars (the red planet of solar system) (CIP, 2017; Mosher, 2017). The domestic demand for potato (*Solanum tuberosum* L.) in India will be around 125 million tonnes by the mid of this century (Rana, 2015). To achieve this, about 15.63 million tonnes of good quality seed potatoes will be needed. This requirement is about 2.5 times higher than the present level of seed potato production in India. In early 1940-1960's, seed potatoes were produced only in hills through clonal multiplication. This was in practice to avoid the aphids that otherwise serve as a vector that spread viruses and viral diseases. This barrier was broken with the development of seed plot technique.

Globally, about 36 million tonnes of seed potatoes were cold-stored and this resulted in the global production of 379.75 million tonnes of potato during 2016 (FAOSTAT, 2017). In India, approximately 6 million tonnes of seed potatoes were kept in cold stores during 2015. With the assistance of seed lot and cold stores, India was able to produce 45.57 million tonnes of potato during 2016 (at the seed rate of 2.5 tonnes/ha) (Paul *et al.*, 2018).

Usually, potato crop is multiplied vegetatively using the tubers as the seed material. However, on repeated use the seed material gets degenerated very

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fast and this necessitates the replacement of basic seed material, ideally every year or at least after every two years (Naik and Buckseth, 2018). Even today, quality seed material is either not available or is beyond the purchasing capacity for majority of farmers due to high prices. The importance of quality seed material in potato can be judged from the fact that this alone can add to the yield enhancement of up to 15-20% (Shaheb et al., 2016). The multiplication ratio of the conventional seed potatoes ranges from 1:8 to 1:15, depending upon - cultivars, stage, weather conditions and crop management practices.

The multiplication of seed potato takes a longer time which is equivalent to one cropping season (approximately 4 months). So, to meet the present and future demands, the multiplication rate needs to be still higher and the whole process should also need to be faster. Therefore, alternative methods of seed potato production are needed. Keeping in view, alternative methods should be rapid, low-cost and they must yield good quality seed potatoes which can fit well into the existing potato production system. In the recent past, considerable progress has been made in alternative ways of potato propagation and several rapid multiplication techniques have been developed (Singh *et al.,* 2019; Buckseth *et al.,* 2020).

ALTERNATIVES FOR SEED POTATO PRODUCTION

Tuber sprout technique

Disease-free tubers are the starting material for seed production. Scooping of apical eye plugs is done to break the apical dominance and this leads to multiple sprouting. In this technique, sprouts are repeatedly harvested from mother tuber. The multiplication potential can be enhanced by further cutting the sprouts into pieces (each having one or two nodes). The de-sprouted mother tubers can also be used as normal seeds. Detached healthy sprouts are then planted in polythene bags filled with soil: farmyard manure (1:1) mixture and are grown under the shade. Once the sproutings are established, they are transplanted in the field. Depending on cultivars, 3-4 harvesting of sprouts can be taken from a mother tuber at an interval of 15-20 days. Harvested sprouts can be stored at 6-7°C in diffused light in perforated polythene bags for simultaneous planting after rooting in moist sand.

The other way of raising a successful crop from sprouts is to either bury the well-sprouted indexed tubers in the moist sand: soil (1:1) mixture in shade and on rooting (in 8-10 days), the sprouts can be detached and transplanted directly on the southern phase of ridges in evening hours. Secondly, tubers with multiple sprouts are planted at a distance of 1.0 m in the field and on emergence the shoots can be separated but by leaving atleast 1 or 2 shoots on mother tuber itself.

Now transplanting within the gap of two mother tubers at a distance of 10-15 cm can be done. The mother tubers can again be planted at their respective places. The transplants need to be irrigated immediately. Overall, this technique offers a simple, easy and effective way that can yield 40-100 plants from a single tuber in 2-4 months.

Synthetic seed

The earlier possibility of developing synthetic seed technology in potato was tried by making use of *in-vitro* grown nodal micro-cuttings. In this method, single-node cuttings (5 mm long) are encapsulated with calcium alginate-MS solution. The encapsulated node cuttings form small whitish capsules referred to as beads. These beads are then incubated under light (with 16 hours of photo period) for germination and the germinated beads can be planted in soil. Application of rooting hormone at the time of planting in the soil has been found highly effective in the early establishment of roots and thereby in the proper growth of seedlings arising from the synthetic seeds. Production of virus free potato synthetic seeds and seedlings using tissue culture techniques were further refined by El-Abhar (2018).

True potato seed

True potato seeds (TPS) is not a suitable technique for rapid multiplication but it is an alternative technology for raising crops from true botanical seeds of the potato plant. It is there by referred to as potato seed and not the seed potato. The TPS technology consists of production of botanical seed (TPS) and raising the crop from the same. Seeds are extracted from berries of potato plant and they are processed and stored. The TPS can be stored for a long period. Even after eight years of storage, the germination is reported up to 96%. Only 100-150 g of TPS (costing about ₹ 3,000) are sufficient to raise the crop in one hectare. This is in contrast to the requirement of up to 3-4 tonnes of conventional seed potato tubers (costing about ₹ 25,000). The TPS technology, besides being low in cost also reduces the problems related to storage and transportation as faced due to bulkiness of the traditional seed potato tubers. Additionally, the spread and the intensity of seed-and soil-borne diseases are also significantly less in the crop raised from the TPS.

In India, TPS technology is likely to gain in Karnataka, Maharashtra, Madhya Pradesh, Orissa and in North-Eastern states including Meghalaya, Manipur, Arunachal Pradesh and Nagaland where good quality

seed tubers are either not available or they are too expensive (Sharma and Dhakar, 2013). Considering the unfavourable situations in the North-Eastern regions of India for the production of breeder seed, TPS can be a viable alternative in meeting the demands of quality seed potatoes. In this direction, Sharma and Dhakar (2013) examined the demand forseed potatoes and the potential of TPS technology in these regions. It was concluded that as the rate of degeneration of traditional seed potatoes is high in the main seed production areas of North-Eastern regions, the TPS technology offers solutions to the prevailing problems.

This was the conclusion of the above workers even though TPS technology is labour-intensive. A workable strategy for the large-scale adoption of TPS technology was suggested by Sharma and Dhakar (2013). In Meghalaya, Manipur, Arunachal Pradesh and Nagaland, where potato is grown in two seasons, TPS technology was recommended for the production of tubers in one season (autumn) and utilization of the same (as disease-free quality planting material) in the subsequent main-cropping season (summer).

There is a strong scope of replicating the success story of Tripura state in terms of large-scale adoption of TPS technology to other North-Eastern states, particularly for Assam as it has enough potato production potential, however, it has remained untapped so far. There is sufficient justification for utilization of TPS as produced by Tripura for all the seven North-Eastern states of India. Muthoni *et al.* (2013) suggested that more emphasis is given on the potential and prospects of TPS which might alleviate the shortage of seed potato tubers in specific regions of India and also in other developing countries. The technology of mini-tuber production through TPS under aeroponics has been standardized at ICAR-CPRI, Shimla (Buckseth *et al.*, 2019a).

Micropropagation

In-vitro multiplication: In view of huge demand of seed tubers, micropropagation might serve as an alternative method of seed multiplication. Many well-defined *in-vitro* techniques are now available for potato. Each technique basically starts with a healthy piece of plant part or tissue. Being a member of Solanaceae family, potato is highly amenable for rapid multiplication. In case of non-availability of health-related information of plant or plant parts, healthiness status of the plant or plant part can be enhanced by thermotherapy and chemotherapy. Some rapid multiplication techniques, suitable for potato are as follows.

Stem cuttings: In this technique, big size healthy tubers with multiple sprouts are planted in pots at shallow depth. After emergence and when the multiple sprouts are 10-15 cm long, the terminal growing tips are cut (decapitation) to promote the growth of lower axillary buds. The axillary shoots are then harvested after every 5-10 days by taking 4-6 cm long apical segments and leaving 1 or 2 leaves at the base for regrowth. Fertilizer application to the mother tuber is essential after every harvesting for its rapid and sustained growth. The harvested stem cuttings are rooted on sand beds and then transplanted in soil either in field or in polythene bags. For proper and rapid rooting, treatment of rooting hormone powder (such as Seradix-B No. 1) can be given to cuttings just before planting into soil. This method can produce 25-100 stem cuttings from a single mother plant in 2-3 months.

Meristem tip culture: This technique is based on the fact that even in the infected plant, the apical and axillary meristems of 0.1-0.3 mm length are generally free from viruses. So, this technique involves dissection of a small growing portion (0.2-0.3 mm) of apical or axillary meristem and culturing the same on nutrient medium for regeneration. In general, larger the size of the meristem tip, better is the chance of survival and smaller the size of meristem, higher is the chance of its being completely free from viruses. By using this technique, many potato genotypes have been successfully made free from various potato viruses that are otherwise common and very much prevalent in India.

Nodal cuttings: Nodal cutting is another method that is preferred over any other method as it offers the lowest possible chance for introduction of any genetic modifications. Rapid multiplication *via* nodal cutting is commonly done when there is a demand for a huge quantity of seed potato and this needs to be furnished within a short period (Naik and Buckseth, 2018). This facilitates the production of 3-8 plantlets in each cycle that takes about nearly four weeks. When new plantlets attain a good root system, they are moved to potting medium under the green house, followed by gradual hardening to make them perfect to be planted in the field or net-house for the production of mini-tubers. Mini-tubers are miniature tubers (having a size of 0.5-2.5 cm) capable of producing potato plants in the field and they are usually free from viral and other diseases.

Micro-tubers: Micro-tubers, also called as *in-vitro* tubers that are small-size tubers produced under *in-vitro* conditions (in the medium under controlled environment) either on the complete plantlets or on the plant parts. So, micro-tubers are miniature seed potatoes produced under *in-vitro* conditions from the cultured plant part. They represent the first generation of nuclear seed potato having weight, diameter and length ranging from 0.024-0.273 g, 0.40-0.77 cm and 1.0-1.2 cm, respectively. Mini-tubers are then produced by growing micro-tubers in greenhouse. The term mini-

tuber refers to the size as they are smaller than the conventional seed tubers but larger than the micro-tubers (Sharma and Pandey, 2013). The weight and size of mini-tubers may range from 0.1-5.0 g (or even up to 10.0 g) and 0.5-2.5 cm, respectively.

Presently, under hi-tech seed production system, production of micro-tubers (representing nucleus planting material) is being done in the lab under controlled conditions using the techniques like micropropagation, hydroponics and aeroponics (Chiipanthenga *et al.,* 2012; Chindi *et al.* 2013; Pandey, 2014).

Semi in-vivo multiplication: The best example for this condition are screen houses in the open field, glass houses or protected structures. The potato crop is highly a menable for rapid multiplication as it can give its progeny through different parts of the plant. Under semi in-vivo conditions, the following multiplication systems have become well established and they are briefly presented below.

Microplant based seed production system: Three to four weeks old microplants are either transferred to portrayfilled with sterile peat moss. The microplants can be planted in portray with root or without root (cuttings). For planting with root, media sticking to the root should be properly washed off. After transplanting, drenching is done with the Mancozeb (0.25%) solution. The portrays are then transferred to the growth chambers and kept in dark for 48 h and subsequently in 16 h photo period for 2-3 days. Once the plantlets are established in port rays (4-5 days), these portrays are transferred to the hardening chamber and kept at 27°C for 10-15 days. The hardened plantlets should be removed from portrays along with peat moss and transplanted on nursery beds in a mixture of soil, sand and FYM (2:1:1) in rows at 30 × 10 cm spacing under insect-proof net house (Naik and Buckseth 2018). About 5% of the plants are usually tested by ELISA.

Roguing is done for all virus-infected plants, off-type plants, abnormal and stunted plants as observed during the inspection. Then the microplant crop is allowed to mature and finally harvesting is done for mini-tubers. Each microplant can yield 8-10 mini-tubers. Seed crop should be harvested 15-20 days after haulms cutting when tuber skin is hardened. The seed tubers thus produced are called as mini-tubers. Curing is then done by keeping the seed tubers in heap for 15-20 days in a cool shady place. After curing, mini-tubers should be graded into >3 g and treated with 3% solution of boric acid for 10-15 minutes to prevent surface-borne inoculum. Mini-tubers harvested from microplants (Generation-0) are called as nucleus seed. Storage of mini-tubers can be done in a country store in hills and a cold store (at 3-4°C) in plains. Mini-tubers weighing > 3g can be planted in field during the next season (represent the Generation-l). Whereas, < 3g mini-tubers can be recycled once again under controlled poly / net house conditions (again representing Generation-0). If the crop produce now meets the criteria, then it can be used for raising the Generation-1 crop in field.

Micro-tuber based seed production system: Multiplication of micro-tubers can be taken up in net-house to get seed tubers. For this, beds are prepared with soil + FYM (1:1) mixture. Basal dose of NPK @ 25% can be given at the time of bed preparation itself. The micro-tubers produced under in vitro conditions are now planted (after their proper sprouting) on beds in net-house (usually during the second or third week of October) at the spacing of 10 cm × 10 cm or 10 cm × 20 cm and at a depth of 2-3 cm (Buckseth *et al.,* 2017). There are variations in size of micro-tubers so, small-sized micro-tubers can be planted at shallow depth (upto 1-2 cm) and the large-sized micro-tubers can be planted a little deep (up to 3-4 cm). Sorting of micro-tubers for their grading as per their size need to be done at the beginning itself, *i.e.* before taking up the planting.

Bioreactor technology for mass production of micro-tubers

A simple protocol for mass propagation of potato micro-tubers was developed by using an automated low-cost bio reactor system. This involved a two-steps culture method. In the first step, the stock plants were inoculated in the bio reactor for the growth and multiplication of plantlets. After four weeks, medium was replaced with a new one to proceed to step second for micro-tuber induction. It was observed that multiplication and growth were more efficient in continuous immersion bioreactors. Maximum responses were recorded when there were 50 nodal explants per bioreactor. After shoot proliferation, culture medium was replaced with a medium containing a higher concentration of sucrose [with or without 6-benzylaminopurine (BAP)] under dark conditions.

The addition of BAP in the culture medium was found to influence the formation of micro-tubers larger than 1.1 g. There was also a strong influence of medium renewal on individual micro-tuber growth during bioreactor culture of potato. This system was suggested as a low-cost system for mass propagation of potato tubers. This method has the potential to produce 80 micro-tubers from 50 explants in 1.5 litres of MS medium in 10 litres capacity of temporary immersion system bioreactor. Later, Perez *et al.* (2008) have harvested 229 micro-tubers from 80 explants in 600 ml of medium in a 5 litres capacity of bioreactor. Bioreactor based system facilitates automation, quality control

and synchronous material development and all this add to the efficiency and profitability. In addition, bioreactor when combined with techniques of inducing somatic embryogenesis then it further offers a promising tool for mass propagation (Rokka *et al.,* 2013).

Hydroponic system

This technique is more efficient than conventional method of seed potato production in soil (field). Productivity in a hydroponic system is 2-3 times more. During the crop cycle, tubers can be harvested in batches (3-5 harvesting, as and when they reach the right size). This technique facilitates continuous and adequate supply of nutrients to the mother plants, facilitating multiple harvesting of mini-tubers during the period of production cycle. Like any other alternative method, this technique also avoids an attack by pests and the dissemination of pathogens. So, tubers produced are normally disease-free.

Aeroponic system

Under an aeroponic system, an individual potato plant can produce up to 100 mini-tubers, while in conventional method, on average 8-10 daughter tubers are produced. Like micro-tuber production, starting material for aeroponic method also needs to be virus-free and therefore it is obtained by meristem culture. Aeroponically produced mini-tubers are thereby free from viruses and various soil-borne diseases and infections. These mini-tubers can be planted directly in the field without any need for acclimatization. It was the aeroponic system that resulted in highest multiplication (production of 47 mini-tubers / plant). This was in comparison to nutrient film technique (NFT) and deep film technique (DFT), where multiplication reaches 35 and 37 mini-tubers / plant, respectively (Factor *et al.,* 2012).

Various advantages and merits of the aeroponic system in seed potato production are: (1) being a hydroponic based system, aeroponic system makes effective use of vertical space and in this way requirements of additional land, soil and natural environment are overcome. All this is of definite advantage because additional availability of any land for agricultural is now gradually becoming difficult and in future, it will become almost impossible, (2) feasible to accommodate high-density planting and thereby higher crop yields, (3) this technology is eco-friendly. In recently conducted NASA sponsored research, aeroponic systems under ideal and optimized conditions can reduce water use by 98%, fertilizer use by 60% and pesticide use up to 100%, and gives yield higher by 45-79%, (4) provides high multiplication rate. As per CIP, up to 70 seed tubes can be obtained in 180 days from one plant against 5-6 tubers / plant in 90 days when conventional method is used.

Mini-tubers produced under an aeroponic system can be harvested on a routine basis as and when they attain an optimum size of 3-4 g. The harvested mini-tubers are sub-sequently cured in decreasing humidity and temperature and then they are finally stored at 2-4°C for future use (as planting material in subsequent seasons), (5) once established and functional, aeroponics is not labour intensive and in long-run it proves to be highly cost-effective, (6) among all the alternatives, aeroponics has an edge for quality seed potato production and therefore this system is gradually gaining over the other methods. It is gradually replacing in-vitro methods of micro-and mini-tubers production and (7) potato aeroponics that too at commercial scale is already started. Besides the developed nations, commercial production of seed potatoes using aeroponics is already in progress in China, Korea, Vietnam *etc*. This technology is expected to revolutionize seed potato production in developing countries (Chiipanthenga *et al.,* 2012).

The ICAR-Central Potato Research Institute (CPRI), Shimla, Himachal Pradesh, India, has also developed an aeroponic facility for rapid multiplication of quality planting material of potato. This was in view to meet the growing demand for quality and disease-free propagation material. This will assist in making the country self-reliant in seed potato production. A prototype of an aeroponic unit was devised with a production ability of about 30-35 mini-tubes / plant against 8-10 tubers in conventional methods. Further progress has been made in the last few years as aeroponic facility has now been created at CPRI, Shimla, Modipuram, Patna and Shillong. The entire North-East region of India is not suitable for production of potato breeder seed through the conventional method and this is due to the high levels of aphid population during crop season. This results in a high rate of degeneration due to viral diseases and soil-borne infestations.

Therefore, micropropagation (via nodal cuttings of potato) followed by multiplication of mini-tubers in net houses are the options available for production of high-quality seeds in this region. But, low productivity (6-8 tubers / plant) and frequent incidence of soil-borne diseases emerged as major constraints. In this situation, one feasible solution is to adopt a soil-less seed production system. Bag *et al.* (2015) showed that an aeroponic system can be successfully utilized for augmenting the production of tissue-culture based disease-free and quality seed potato in North-Eastern regions of the country. However, non-uniform performance of varieties over the years has also called for cautious optimism in widespread use of this technology.

A study by Rykaczewska (2016) concluded that aeroponic system offers a viable technological alternative for potato mini-tuber production but cultivars do play a significant role in deciding total number of mini-tubers produced. So, aeroponic system requires a study with full economic analysis; including energy cost, labour cost and amortization of material specific to aeroponics to prove that this production technique can be put into practice. Mbiyu *et al.* (2012) put forward positive aspects of the aeroponics technique with affirmation with some more and new practical and technical details. Some additional and important aspects were also pointed out in the above study (Mbiyu *et al.*, 2012).

It is quite clear that aeroponic system of seed potato production has the potential to once again revolutionize potato seed production sector after about 50 years of introduction of "seed plot technique". So, ICAR-CPRI, Shimla is making continuous efforts in making aeroponics more cost-effective and efficient. The institute has also started moving in the direction of commercialization of this technology for its rapid growth in India (Buckseth *et al.*, 2016). In this regard, a Business Planning and Development (BPD) unit has been established at Jalandhar, Punjab. The workable aeroponic system has been commercialized to 14 firms of Uttar Pradesh, West Bengal, Punjab and Haryana. Each firm is now licensed to produce about 1.0 million mini-tubers by using aeroponic system (Singh *et al.*, 2019).

The Mahindra Agri Solutions Limited (MASL) of India and HZPC (a Dutch-based supplier company for seed and ware potatoes) have opened up a modern and joint state-of-the-art aeroponic facility at Mohali, Punjab, in 2016 for production of seed potatoes. This facility was expected to generate 3.0 million mini-tubers. Its first production batch was already supplied in January 2017. Availability of virus-free quality seed will enhance potato production and productivity by 10-30% in the region besides increasing the net incomes of farmers.

With the support of this facility, Mahindra-HZPC has additionally planned to launch six new potato varieties, three of them will cater to the needs of end consumers and the remaining three are being targeted for processing purposes (Fresh Plaza, 2016). Aeroponics seems to have a lot of scope in augmenting seed potato production in our country. Aeroponics, being a new technique for seed potato production in India, optimization of several factors needs to be addressed (Buckseth *et al.*, 2016). The technology of mini-tuber production through TPS under aeroponics has also been standardized at CPRI, Shimla (Buckseth *et al.*, 2019a). Recently, refining an aeroponics system for seed potato production till full crop season has been done (Buckseth *et al.*, 2020).

Techni-tubers

Imperial Tobacco Company of India (ITC, India) in collaboration with Technico Pvt. Ltd. (Australia), with a trading name 'Technico', has developed a technology for rapid multiplication and varietal improvement by using small-sized tubers referred as TECHNITUBER® (Technico Pvt. Ltd., 2015). The centre for this facility is located at Manpura in Himachal Pradesh. They can be used as quality planting material in potato production system (Technico Pvt. Ltd., 2015). As per initial work and the patent on Techni-tubers by Dowling (1995), Techni-tubers represent unique potato propagules that can be produced on a round the year basis at low cost. As per the above patent report, Techni-tubers offer a real opportunity for changing the pattern of seed potato production. They are miniature seed potatoes (approximately 1.0-1.5 cm in diameter).

Production of Techni-tubers occurs under controlled environmental conditions and thereby there is full control on growth and development of potato plant and tubers including on the process of tuberization. Available data show that 101.28, 94.71, 85.10, 108.43, 131.27 and 106.58 lakh of TECHNITUBER® (seed potatoes) were produced during 2011, 2012, 2013, 2014, 2015 and 2016, respectively and they were distributed across India for cultivation of potato (http://www.itcportal.com/about-itc/shareholder-value/annual-reports/itc-annual-report-2012/pdf/TECHNICO_AGRI_SCIENCES.pdf; http://www.itcportal.com/about-itc/shareholder-value/annual-reports/itc-annual-report-2014/pdf/Technico-Agri-Sciences-Limited.pdf; http://www.itcportal.com/about-itc/shareholder-value/annual-reports/itc-annual-report-2016/pdf/Technico-Agri-Sciences-Limites.pdf)

Apical rooted cuttings

A novel low-cost and farmer-friendly technology called Apical Rooted Cutting (ARC) has recently been standardized by CPRI, Shimla, for hi-tech seed production in potato. The ARC involves raising in-vitro plantlets in nursery and then transplanting of rooted-cuttings in glass/net-house (Buckseth *et al.*, 2019b). Rather than allowing tissue culture plantlets to mature and produce mini-tubers, multiple cuttings are produced from an individual plantlet. The study has shown remarkable results which suggest that technology can be used for production of quality planting material at low cost in seed deficit areas. The everlasting shortage of seed potatoes can also be partly overcome through ARC on account of its faster rate of

multiplication.

Little tubers

Normal potato tubers when stored for a long-period (more than six months) at 10°C, become old (aged) and then they start producing little tubers on them (sessile tubers). These small-sized tubers produced directly on physiologically-aged mother tubers are referred to as little tubers. Thus, little tubers can be produced directly on physiologically-aged mother potato tubers. Although, this is an old technique and is a highly cost-effective alternative for production of quality and pathogen-free potato propagation material. The size of little tubers ranges from 0.1 to 5.0 g. The way in which the production of little tubers is done, makes them different and distinct from all methods of micro-tuber and mini-tuber production.

Induction and production of little tubers: Low-temperature exposure was found to be beneficial in bringing about early induction of little tubers on mother tubers (a process comparable to tuberization in field). Longer duration of initial low temperature (2-4°C) exposure (induction period) reduces the duration of storage period that is otherwise required for initiation of little tubers. Based on initial low-temperature exposure (2-4°C) and / or subsequent storage of mother potato tubers at different temperatures (6°C, 18-20°C and 25°C). Various protocols were developed for little tuber induction / production. All the protocols require the storage of mother tubers in complete darkness. Initial low-temperature exposure at 2-4°C and then repeated de-sprouting (3 times) during the subsequent storage at 18-20°C was found to be the best for the induction and production of highest number of little tubers. With this method, on an average, 12 little tubers (ranging from 0.25 to 0.50 g) were produced on a single mother potato tuber.

Further improvement in terms of earliness and efficiency of little tuber production was achieved when initial low-temperature exposure to mother tubers was followed by spray treatment to mother tuber with a growth retardant (triadimefon @ 100 ppm) during the storage at 18-20°C. This treatment basically decreased the days required for induction of little tubers by about 12-63 days (depending on the variety). In addition to this, the treatment also reduced the number of little tubers weighing from 0.1 to <0.5 g by 61% and enhanced the number of little tubers with weight ranging from 0.5 to ≥ 1.0 g by 34%.

These improvements were highly desirable and beneficial because: (1) this cut short the total storage duration requirement for the production of little tubers and (2) little tubers, weighing 0.5 to ≥ 1.0 g, are known to perform better when sown directly in the field conditions in comparison to the little tubers weighing less than this range. With the present method, 8-15 little tubers (depending on variety) can be produced per mother tuber within 10-12 months. Out of total number of little tubers, 6-8 little tubers fall within the range of 0.5 to ≥ 1.0 g and as stated above, they are suitable for direct planting in the field (Paul *et al.*, 2015). Step-wise protocol and schedule for production of little tubers and their use in potato crop production in plains as well as in hills were reported by Paul and Ezekiel (2013).

Dormancy and sprouting behaviour of little tubers: In comparison to dormancy period of normal potato tubers (57-65 days), little tubers have very-long dormancy period (115-132 days). Dormancy of little tubers was found to be linked with their size or weight. Smaller the size of little tubers, longer was the dormancy duration. In comparison to normal seed potatoes, producing 1.4-6.0 sprouts per tubers, little tubers produce only single sprout. After the dormancy break, growth of the sprout on little tubers is very slow. Sprout length of little tubers reaches to 1.2 and 1.5 cm after 110 and 180 days of storage (18-20°C), respectively. While, under similar conditions and durations of storage, sprout length of normal seed potato tubers reaches to the length of about 5.6 and 10.0 cm, respectively.

Field performance of little tubers: Direct sowing of little tubers can be done in field. For this, either freshly harvested little tubers [after giving the dormancy breaking treatment (using a dip treatment for 1 hour in a solution containing 1.0 ppm of GA and 1.0% of thiourea)] or little tubers harvested during previous year (and stored in cold store at 2-4°C with RH 90-95%) can be used. Little tubers weighing 0.5-1.0 g were found to yield at par with that of conventional seed potatoes (40-60 g) when sown directly in the field at half of the spacing, *i.e.* 60 cm × 10 cm instead of normal spacing of 60 cm × 20 cm (as followed for 40-60 g of conventional seed potatoes). The crop raised from little tubers produced more tubers than normal seed tubers but total yield was almost comparable in both cases. Progeny of little tubers were also found to be at par with that of conventional seed potatoes in terms of vegetative growth and yield. Little tubers yielded more in field in comparison to micro-tubers and were almost at par compared to normal tubers at double the planting density (by reducing the spacing to half) but, the overall size of tubers produced was smaller.

Merits of little tubers over conventional seed potatoes: Little tubers weighing 0.5-1.0 g offers various merits as planting material in potato production system over the conventional seed potatoes. These merits are as follows: (1) little tubers are virus and pathogen-free.

If the starting mother tuber is free from virus and pathogen then the little tubers produced on it will also be free from any virus and pathogen as they are produced under indoor and controlled conditions, (2) in a small space with controlled conditions (mainly for the temperature and humidity), the large number of little tubers can be produced, (3) production of little tubers is cost-effective. No land, water, fertilizer or pesticides are needed, (4) size of little tubers (weighing 0.5 - ≥1.0 g) is bigger than *in vitro* produced micro-tubers (weight 0.024 - 0.273 g). Unlike micro-tubers, little tubers can be planted directly in field. When planted at half of spacing, little tubers yield at par to the conventional seed potatoes. With the size of little tubers of 0.5 - ≥1.0 g, inherent problem of proper and timely crop establishment in the field (as faced by *in-vitro* produced micro-tubers) can be eliminated, (5) like the micro-and mini-tubers, handling, packing, transportability and storage of little tubers is easier and cost-effective, (6) after the dormancy breaking treatment, little tubers produced in plains can be used for planting in hills and vice-versa can also be done, (7) if little tubers are already produced during the previous year/s and kept well in a cold store at 2-4°C with 90-95% RH, then they can be used for taking the usual potato crop either in plains or in hills and (8) the progeny of little tubers can also be used as propagation material without any degeneration in terms of yield and quality aspects.

Potential and scope of raising mini-tubers: Various developments made in field of *in-vitro* production of potato plantlets by using disease-free material along with the recent progress that has been made in the area of mini-tuber production by the use of aeroponics have in fact revived the area and potential application of little tubers. Now, little tubers can supplement the ongoing use and practice of making use of *in-vitro* produced micro-tubers or disease-free potato plantlets for the production of mini-tubers either in glasshouse or by the use of aeroponics. With this possibility, little tubers (in comparison to *in-vitro* produced plantlets or micro-tubers) offer a highly cost-effective option of providing disease-free and quality propagation material. Little tubers, even those weighing < 0.5 g, can also be utilized for: (1) production of in vitro plantlet and then for mini-tuber production (by aeroponics) and (2) production of mini-tubers either in glass-house or directly under the aeroponic system.

In future, research attempts are however needed to reduce the overall time taken for production of little tubers from the existing duration of 10-12 months to 6-7 months or even lesser than this. This change will not only remove the basic bottleneck in making use of little tubers in the existing system of potato production but it will also make the little tuber production technology more practical and economical. Further, achieving a higher multiplication rate of about 15-20 or more is required for little tubers weighing 0.5 - ≥1.0 g. This will help in making the little tubers technology more efficient, more potent and acceptable as seed material.

Utilization of under-sized tubers left in the field

Potato being a vegetatively propagated crop allows the use of its tubers (weighing 40-70 g) as the seed in conventional potato production. Potato tubers of very small size (weighing < 20 g) are usually left in the field itself, especially after mechanical harvesting. As such, potato tubers of this size are not suitable for conventional seed purposes. Making use of these small-size and left-over tubers which are of otherwise no use is open option. If size of these tubers(< 20 g) is enhanced to an acceptable level of 40-50 g, *i.e.* equivalent to conventional seed potato tuber size by seed pelleting along with the addition of nutrients, then such tubers can also be used as suitable planting material. Seed pelleting is a technique of coating seeds of small size for the purpose for increasing their size.

CONCLUSION

Shortage of quality seed potatoes is a major and a key problem in developing nations. Only about 11% of the world's potato crop is grown from quality and certified seed. Due to this shortage, many a times the potato production often occurs or continue to occur with the degenerated seed material. Degeneration occurs due to successive accumulation of pathogens and pests (viruses, bacteria, fungi and mycoplasmas) in the propagation material over a period given the repetitive cycle of vegetative propagation. Thus, it indicates availability of different alternative methods of seed potato production should be there. As a part or step towards the spread and commercialization of different alternative techniques in India, Mc Cain Foods India Pvt. Ltd., Simplot India Pvt. Ltd., Bhatti Farms (Jalandhar, Punjab) and Shivalik Seeds (Meerut, Uttar Pradesh) are multiplying seeds of different cultivars of potato at large-scale for the supply to farmers across India.

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Pruning in guava *(Psidium guajava)* — a review

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ABSTRACT

Guava a pruning responsive crop. It is usually performed to establish, maintain and adjust the plants for its intended purpose. It is done either to stimulate vegetative growth of plant which are especially low in vigour or to reduce the excessive vegetative growth. It is also done for consistent fruitfulness of trees that have declined in production over the time. Fruit size, quality, yield and crop regulation can be altered by precise pruning technique. Pruning has great influence on tree canopy management under high-density planting system. The pruning intensity has profound effect on flowering and fruit bearing in guava. Severely pruned trees give lower yield with poor quality. For crop regulation trees required to be pruned in May which encourage good crop in winter season. Old and unproductive guava trees can also be revived for good crop, after proper pruning application.

Key Words: Pruning, Rejuvenation, Fruit quality, Canopy regulation, Light interception, Tree growth, Yield

Guava (*Psidium guajava* L.) is an evergreen fruit well adapted to a wide range of soil and agro climates. It bears flowers and fruits on the current season shoot on recently matured shoots either from lateral buds of older wood or shoot terminals (Thakre *et al.*, 2013). Guava is highly perishable in nature hence, should be marketed immediately after harvesting, the post-harvest deterioration in fruits occur as a result of physiological changes, spoilage losses, dehydration and mechanical injury (Singh *et al.* 2015). Guava occupies an area of 2.62 lakh ha with annual production of 36.48 lakh tonnes during 2016-17 and is a rich source of vitamin C and fair source of calcium, phosphorous, roughage and is ideal fruit for nutritional security (Bairwa *et al.*, 2020). Increase in number of current season's shoot significantly influenced the productivity of guava. Though it bears flowers and fruits round the year but winter, summer and rainy are principal fruit bearing seasons. Pruning is an important tool for increasing the fruiting points in guava trees; however, it influences the particular phenological stage. Scientifically pruning is a judicious removal of plant parts to bring balance between vegetative and reproductive growth of tree.

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Physiology of pruning

The removal of buds in pruning led to reduction of leaf area, and fruit and removal of cambial tissue, loss of secondary growth. Shoot growth in pruned trees significantly increased as compared to un-pruned trees however, trunk and root growth are greatly decreased. Usually shoot growth is stimulated by pruning, particularly heading back of stem, after removal of terminal shoot portions and lateral buds etc. Heading back cuts altered hormonal balance among the remaining buds on the shoot. While as in thinning cuts where entire shoot is removed, did not alter hormonal status. Heading back and thinning out results removal of terminal meristem which are the seat for ample auxin contents and undisturbed root tissue continue to produce cytokine in inclined towards cytokine in which stimulates cell division ultimately shoots growth.

The apical portions of fast growing shoot apex, starts producing auxin and gibberellins in the large quantities which enhanced shoot growth. Heading back of branches, removes terminal meristem and inter-related apical dominance. Removal of apical branch portion leads to proliferation of lateral buds, resulted excessive shoot growth and bushy type canopy. The

distal buds on a shoot have greater growth potential than basal buds. Similarly, buds which are located higher on the canopy have strong, growth potential than lower buds, changing the orientation of branches from normal vertical growing shoots to a more horizontal position which ultimately reduced the rate of bud growth.

Source-sink relationship

Photosynthesizing organ in plant is known as source, mainly mature leaves, produce photo-synthates, especially carbohydrates. Modern fruit growers try to manipulate the source-sink relationship to guarantee adequate fruit production and quality. According to Park (2011), balance between vegetative and reproductive growth of a tree is of great importance for growth and fruit production. Training and pruning alters the balance between vegetative and reproductive growth by allocating the resources. *i.e.* carbohydrate, water and growth regulators. Heavy pruning diminishes leaf area, whole tree photosynthesis and translocation of photosynthates to fruit and roots, increasing the root, shoot ratio (Casierrt-Posada and Fischer, 2012) and favoring growth. During the reproductive phase, pruning, helped to improve the fruit load, regulate the physiological balance (vegetative and reproductive), ensures a harmonious and rational distribution of high quality fruit.

Carbon dioxide assimilation

There was decreased in internal CO_2 in non flowering branch as compared to flowering. It also indicated that there was faster rate of assimilation of CO_2 in leaves of pruned branch as compared to un-pruned. At 50-100 ppm of CO_2 level, no photosynthesis took place. The rate of photosynthesis was gradually increased with increasing concentration of CO_2 and maximum photosynthesis (15 m mol M-2 S-1) was obtained in 450 ppm and 350 ppm concentration of CO_2 in pruned trees of Allahabad Safeda and 'Sardar' guava respectively. In case of high concentration of CO_2, inhibition in photosynthesis rate was recorded; It started declining after 450 ppm concentration of CO_2. Increased in the photosynthesis rate might be due to increased in the efficiency of Rubisco under elevated CO_2 or reduction in photorespiration rate.

Time of pruning

Pruning is important tool for limiting the tree size and improving the fruit quality, it is practiced after fruit harvest in different fruit crops under high density planting system. On the light pruned established branches, large number of flower buds develops, while as plants subjected to severe pruning resulted least numbers of flower buds growth, ultimately less fruit yield. It was observed that delay in pruning from 25 April to 25 June, in 'Sardar', resulted increased in the shoot length, number of flowers, fruit number per shoot, average weight of fruits and yield. It was reported optimum pruning date is February in north-east India and Aswathy and Arumugam (2017) reported mid-March best time. Shoots pruning resulted increased in yield and yield attributes like fruit weight and fruit yield per tree in Lucknow-49 guava at South India. Tree canopy dimension is minimized by regular topping and hedging, dwarf canopy promotes good air circulation and sunlight penetration into canopy center minimizes disease and pest development (Srivastava, 2007).

The phenological development of guava tree was greatly influenced by the pruning practices and heat condition. Guava tree required approximately 800 to 850 heat units and from 1950 to 2000 heat units for pruning to flowering and flowering to beginning of fruit harvest respectively (Ramirez Padilla). Enhancement in winter crop may be due to exposure of stress condition by way of pruning during summer, pruning during summer might have brought down the CHO content of tree to such a level that tree remaining portions have stimulated for vigorous vegetative growth in order to bring the C: N ratio at optimal level.

Pruning for crop regulation

Guava has tendencies to bear crop at different times of the year, but harvesting all amount of fruit is not profitable. The quantum of guava production is very high in rainy season, guava bears most crops in the rainy season, however, rainy season guava is poor in quality, insipid in taste and also fruits are affected by many biotic and abiotic stresses. On the contrary winter season crop gives quality fruits and high monetary profit. This necessitates crop regulation techniques to harvest quality fruits in winter season. Crop regulation has been standardized to induce new vegetative growth during rainy season so that good crop is harvested. Whereas, fruit harvested in the winter season are superior in taste and appearance and having good market demand. Crop regulation for maximum winter harvest is very important in India. The winter crops which ripen in October to January are superior in quality and taste.

Pruning of current season's growth is effective for crop regulation however, 25-52% shoot pruning is reported in 'Sardar' between 20 April to 10 May. It was effective to avoid rainy season flowering and encouraged winter crop. One fourth pruning intensity of 'Sardar' can regulate crop yield without affecting fruit quality under HDP, whereas pruning in May resulted least rainy season crop and increase the winter

season crop (Das *et al.*, 2018; Singh *et al.*, 2015; Agnihotri *et al.*, 2016; and Srivastava *et al.*, 2021)

Application of NAA 600 ppm and 800 ppm for flower bud thinning at one and two leaf pair pruning in May in 'Sardar' guava resulted in low crop in rainy season and high winter crop, however, maximum yield (88.0 kg/tree) was recorded in one leaf pair pruning during winter.

Pruning severity

Severe pruning resulted decrease in the leaf area, tree photosynthesis and translocation of photosynthates to fruit as well as root and increases in the root, shoot ratio (Casierra-Posada and Fischer, 2012), which favors the vegetative growth. Fifty per cent shoot pruning in April and July have positive effect on plant height, canopy spread, stem diameter and plant volume, However, more number of new shoots emerged in April pruned in meadow guava orchard, October pruning did not make any positive effect on fruit quality (Shah and Lal, 2017). Pruning proved to be successful in rejuvenation and reviving yield and quality attributes. Heading back and thinning out resulted removal of terminal meristems which is seat of auxin content while root continue producing cytokin in, which stimulate cell division and shoot growth.

Heading back of young bearing trees in summer helped to improve light penetration inside the tree canopy. Removal of 20 cm shoot tip in early-May, enhanced the leaf numbers and leaf size both in rainy and winter season, pruning in May also increased the fruit size and fruit weight in both season and also improves the fruit quality (Adhikari and Kandel, 2015; Joshi, *et. al.*, 2016).

Pruning for yield

Pruning in evergreen tree was unusual practice, accidental damage of branches *etc.* lead new growth on which flower and fruits borne. Pruning intensity has profound influence on flowering and fruiting, removal of 15-30 cm of branches adversely affected the flower production and ultimately reduced fruit yield per branch and Singh *et al.* (2007) further added that pruning intensity had positively influenced fruit weight and volume. High yield (46.63 kg/tree) was recorded by pruning at 2 m height in 'Allahabad Safeda' (Singh and Singh (2007); Kumar and Rattanpal, (2010); Singh *et al.* (2012). Kumar *et al.* (2009) highlighted optimum fertilization improves fruit yield in guava under eastern India conditions. Further improved in yield and quality were recorded by Srivastava *et al.* (2018), in guava trained on espalier architecture with 65-75% pruning during mid May over traditional system. Increased in yield of pruned tree was due to increased in level of photosynthetic active radiation within the tree canopy.

Pruning significantly decreased the fruit set percentage and fruit number per plant during rainy season and subsequently increased during winter season, since the food reserved in rainy season utilized for winter crop growth. Maximum fruit yield (6.53 and 6.23 kg/plant) noted with thinning out of non-fruiting shoot in winter season planted at 2m × 1m spacing (Nautiyal *et al.*, 2016). The overall increase in winter crop after removal of rainy season crop in May is due to higher accumulation of assimilates which was not utilized by rainy season crop. Light and moderate pruning resulted in highest number of flower buds and fruits were ready to harvest 160-180 days after pruning.

Fruit quality

Open central leader of training system has been found good for quality yield, induction of high fruit quality by different pruning levels have influenced significantly on fruit quality. One-third shoot pruning in summer has significantly increased fruit yield and quality of rainy season guava and recorded total cumulative yield (57.30kg/tree). Guava pruning treatment also increased the pectin content in fruit; it was higher in winter crop as compared to rainy season (Joshi *et al.* (2016); Prakash *et al.* (2012). Pruning height has also notable impact on fruit quality, maximum fruit length, diameter, weight, volume, specific gravity, TSS, total sugars and ascorbic acid content were found maximum in 1.5 m pruning height under HDP (2.0 × 1.5 m); Joshi *et al.* (2016). Moderate and light pruning in guava, resulted in greater fruit weight, in contrast to heavy pruning. In 'Lucknow-49, cultivar, removal of 30 cm of apical shoot in mid March in South India resulted in high TSS, ascorbic acid and total sugar content. Similarly 10 cm shoot tip pruning gave highest fruit yield in contrast severely pruned trees produce smaller fruit and lower TSS and sugar level.

CONCLUSION

One-third shoot pruning in summer had significantly increased fruit yield and quality. For crop regulation 25-52% shoot pruning between 20 April to 10 May is best for crop regulation. May pruning in guava helped to harvest good winter crop.

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Research Article

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Ethnic vegetables for urban nutrition

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ABSTRACT

The use of wild plants as food is an integral part of the culture and tradition of many indigenous communities around the world. Asia can be considered as main gene center for vegetables. In India vegetables and spicy herbs are obligatory compounds of our daily diet which provide high amount of vitamins and bioactive substances. Nevertheless, indigenous vegetables are underestimated concerning their nutritional and economical value in their home states and underutilized so far. The global diversity of vegetable crops is estimated to be around 400 species, of which about 80 species of major and minor vegetables have originated in India. Many of these vegetables could be used as functional foods. Ethnic vegetables are vegetables which are traditionally grown in India. Nutrient-dense indigenous vegetables have a potential role in improving human nutrition. Ethnic vegetables availability is more in rural areas because of this reason urban people prefer exotic vegetables which are less nutritious than ethnic vegetables. The cultivation of these vegetables on larger scale should be increased in urban and peri-urban areas. Home gardening and urban farming need to be enhanced for production of ethnic vegetables to improve the supply to the urban people.

Key Words: Ethnic vegetables, Urban nutrition, Spicy herbs, Bioactive substances, Global diversity

Ethnic vegetables are region-specific, have limited acceptance, part of subsistence production system, no established market and never undergone for any breeding programme. Further, they are native to or originating from a particular region or and naturalized or evolved from introduced materials over a period of time. They are abundant, easily accessible, locally adaptable, cost effective and acceptable in custom and traditions of tribal and settler communities. Many of them are rich in 'protective elements' than exotic counterparts and also have anti-bacterial, anti-viral, anti inflammatory, antithrombotic and antioxidant activities. Ethnic food is defined as a food originates from an ethnic group which uses its knowledge of local plants and/or animal sources (Kwon, 2015). The use of wild plants as food is an integral part of the culture and tradition of many indigenous communities around the world. A large section of rural population meets their nutritional requirement through unconventional means, by consuming various wild plants and animal resources. Millions of people, mostly in developing countries, derive a substantial part of their subsistence and income from wild plant products.

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Ethnic vegetables

Ethnic relating to large groups of people according to common racial, national, tribal, religious, linguistic, or cultural origin or background. Ethnic vegetables are vegetables which are traditionally grown in India. Being culturally, ethnically and ecologically very diverse, several edible wild species available in the forest areas and under utilized species under subsistent agriculture are used by native farmers.

The ethnic vegetable crops are popular and culturally known native varieties. Every region of our country has unique traditional vegetables that are widely consumed by a group of ethnic people, or by a particular community. Hundreds of ethnic vegetables are consumed worldwide in their regions. Traditional vegetables are best defined as species that are locally important for the sustainability of human nutrition, health and social systems. Amongst indigenous vegetables, specifically brinjal, cucumber, snake gourd,

snap melon, ridge gourd, sponge gourd, satputia, spine gourd, bitter gourd, Indian lotus, Indian bean, cluster bean and many other leafy vegetables are important indigenous vegetable in the tropics and possessing good nutrient density and are a rich source of a number of antioxidant, phytochemicals and other micro-nutrients, *viz*. β-carotene, vitamin C, folic acid, magnesium, phosphorus and potassium and are often used in folk medicine. Ethnic vegetables play a significant role in addressing malnutrition, increase farm income for poor farmers, add a range of vital micronutrients to diets and also maintaining the biodiversity. Demand for such vegetables are rising from urban areas, therefore, more acreage under such crops is expected in near future.

Nutritional and nutraceuticals potential

Ethnic leafy vegetables like amaranth and *Basella* are rich in protein and contains several essential amino acids such as arginine, isoleucine, leucine, lysine, the onine and tryptophan. Purslane *(Portulaca oleracea)* has recently been identified as the richest vegetable source of linolenic acid, an essential omega-3 fatty acid. The lack of dietary sources of omega-3 fatty acids has resulted in a growing level of interest to introduce purslane as a new cultivated vegetable in several parts of the world. Drumstick leaves are perhaps the most nutritious vegetable and that is why it is commonly called as Miracle tree.

The leaves and pods are also helpful in increasing milk in the breast feeding mothers. *Basella* is used for its androgenic, antidiabetic, anti-inflammatory, antimicrobial, antioxidant, antiulcer, antiviral, CNS depressant, hepato protective and wound healing properties. Brahmi *saag* is used in the treatment of a number of disorders, particularly those involving anxiety, intellect and poor memory while Indian pennywort *(Centella asiatica)* is used as herbal remedy for skin conditions, wound healing and memory improvement. Water Pennywort is a Chinese herbal drug for hepatoma. The juice of the plant is used in the treatment of fever, and paste made from the plant is applied externally to wounds and boils. A decoction of the plant is used in the treatment of abscesses, boils, bruises, cirrhosis, colds, coughs, hepatitis, hepatoma, influenza, itch, jaundice, sinusitis and sore throat. The leaves of *Oxalis corniculata* are used as an antidote to poisoning by the seeds of Datura spp, arsenic and mercury.

Fortification with ethnic vegetables

The ethnic vegetables have less preference particularly in rich and educated urban people than exotic vegetables. High content of micronutrients in these vegetables can be supplied to children through fortification of their staple foods or fast food items like biscuits, idli, vada, pakoda, sandwich, chutney, paratha, kurkure *etc.* at household or Anganwadi or school (mid day meal scheme) levels. This concept will help in increase in intake of essential micronutrients like Ca, Zn, Fe, β-carotene and ascorbic acid contribute by these vegetables. The concept will assist in targeting the malnutrition along with food security schemes in marginal communities. The powder of drumstick, palak and coriander is used for supplementing the dietary items for pregnant women and children in health conscious households.

Indigenous vegetables in India

Individual indigenous vegetable crops commonly grown in India are discussed in table on next page:

Brinjal *(Solanum melongena)*

India, being a primary center of origin, possesses large variability. The region across India and Indo-China is considered the center of diversity for brinjal. The *Solanum melongena* complex has three species, namely, the *S. melongena, S. incanum* and *S. insanum*. Wild relatives of Solanum *viz*. *Solanum torvum, S. indicum, S. insanum, S. surattense, S. pubescens, S. gilo,* and *S. khasianum* are widely distributed in South India, Shivalik hills and North-eastern region. It is used in various India cuisines, the brinjal is loaded with fiber and nutrients such as potassium, vitamin C, vitamin-B6 and phytonutrients which protect the brain cells from damage, and preserve the memory function. The vegetable also has high water content and so is ideal for people looking to lose weight.

Legumes

The rich legume biodiversity of India with 167 genera and 1,141 species hold great promise in this regard. *Lablab purpureus*, referred to as country bean is one such lesser known legume and its tender pod is a popular vegetable in India, although the seeds are also consumed.

Dolichos bean Lablab purpureus

Dolichos bean is an important legume crop with multiple benefits. In India, it is popularly grown in South, East and North East parts of the country. It is the major source of protein in the South Indian diet. It prefers comparatively cool season, and moreover majority of traditional cultivars are temperature and photoperiod-sensitive and requires short days for flowering. Its green delicious immature pods and seeds are consumed as vegetable. It is very good source of protein (20-25%), amino acids (like lysine, usually lack

Vegetable	References
Cucumber, pointed gourd, Ivy gourd, sponge gourd, ridge gourd, snake gourd, lab lab bean, taro, leafy vegetables, brinjal, dudaim melon, summer squash, jack bean, snap melon, *Basella alba* and *rubra*	Singh *et al.,* 2020
Sponge gourd *(Luffa cylindrica)*, ridge gourd *(Luffa acutangula)*, spine gourd *(Momordica dioica)*, pointed gourd *(Trichosanthes dioica)*,snake gourd *(Trichosanthes anguina)*, snapmelon (*Cucumis melo* var. *momordica*) and ivy gourd *(Coccinia indica)*.	Gangopadhyay *et al.,* 2020
Pursulane, *Alternanthera sessilis*, Wild amaranth *(Amaranthus spinosus)*, crepe ginger *(Cheilocostus speciosus)*, bichho grass *(Nettle leaf, Urtica dioica)*, drumstick *(Moringa oleifera)*, sunnhemp *(Crotalaria juncea)*, water spinach, Indian lotus *(Nelumbo nucifera)*, tree bean *(Parkia roxburghii)* and cluster bean *(Cyamposis tetragonoloba)*	Ram *et.al.,* 2020
Aerva lanata, Alternanthera sessilis, Amaranthus tricolor, Curcuma amada, bird's eye chilli, bittergourd, bread fruit, Centella Asiatic, *Colocasia gigantean, Curcuma amada,* Oriental pickling melon, *Momordica charantia, Momordica dioca, Momordica tuberose, Moringa concanensis, Mucuna utilis, Murraya koenigii, Sauropus androgynus, Sesbania grandiflora, Solanum nigrum, Solanum torvum, Solena amplexicaulis, Talinum triangulare* and *Canavalia gladiata*.	Latha *et al.,* 2020
Kachri, snap melon, long melon, arva, spine gourd, *Mamordica balsaminia, Citrullus lanatus, Citrullus colocynthis, cluster bean, vigna acontifolia, Prosopis cinereria*	Saroj and Choudary, 2020
Drum stick, Basella alba, curry leaf, *Hydrocotyle sibthorpoides, Oxalis corniculata, Polygonum plebeium, Lasia spinosum, Portulaca oleraceae, Diplazium esculentum, Solena amplexicauli, Centella asiatica* and *Bacopa monniera*	Pragya *et al.,* 2020
Allium ascalonicum, Allium chinense, Allium hookeri and *Allium tuberosum*	Kumar *et al.,* 2020
Sorrel *(Rumex species),* Broad bean *(Vicia faba)*	Sharma *et al.,* 2020

in cereals), vitamins (A, C and riboflavin) and minerals (Ca, Fe, Mg, S, Na and P). Moreover, immature pods and seeds are rich in dietary fibre and low carbohydrates and lipids.

Moth bean *(Vigna aconitifolia)*

Moth bean is an important crop of arid and semi-arid regions moth bean seeds are a good potential reservoir of proteins and other essential minerals and vitamins. Mature, raw seeds contain water (9.7 g), energy (343 kcal), protein (22.9 g), fat (1.6 g), carbohydrate (61.5 g), Ca (150 mg), Mg (381 mg), P (489 mg), Fe (10.9 mg), Zn (1.9 mg), vitamin A (32 IU), thiamin (0.56 mg), riboflavin (0.09 mg), niacin (2.8 mg), vitamin B_6 (0.37 mg), folate (649 µg) and ascorbic acid (4.0 mg/100 g) edible portion.

Yard long bean *(Vigna unguiculata subsp. sesquipedalis)*

Yard long bean is one of the most popular and preferred vegetables. It is an annual climbing plant, used as a green vegetable. The pods can be eaten fresh or cooked in a variety of dishes. Young, immature pods are one of the very low-calorie vegetables; 100 g beans contain just 47 calories but rich in protein (4.0 g/100 g).

Cucurbits

India is the home of a large number of cucurbits including cucumber *(Cucumis sativus)*, sponge gourd *(Luffa cylindrica)*, ridge gourd *(Luffa acutangula)*, spine gourd *(Momordica dioica)*, pointed gourd *(Trichosanthes dioica)*, snake gourd *(Trichosanthes anguina)*, snapmelon (*Cucumismelo* var. *momordica*), ivy gourd *(Coccinia indica)*. Luffa has rich diversity in Indian gene centre. Out of 9 species, 7 are native to India. The domesticated cucumber *Cucumis sativus* var. sativus L. originated from its wild progenitor Cucumis sativus var. hardwickii (Royle) Alef. which is found in foot hills of Himalayas.

Bitter gourd *(Momordica charantia)*

Bitter gourd, despite its distinctive appearance and bitter taste, originally from the Indian subcontinent, is popular in a number of Asian countries. The triterpenoid momordicin, responsible for the bitterness of this vegetable, has been demonstrated to have anti-diabetic activities. TCD triterpenoid from wild bitter gourd has been shown to inhibit breast cancer cells (Bai, 2016). Bitter gourd fruit is a rich source of nutrients and ranks first smong the cucurbits for its nutritive value being a good source of carbo hydrates, proteins, vitamins and minerals.

Momordica charantia var. muricata: It is a wild gathered or semi-domesticated small bitter gourd. Fruits are small (20-30 g) and esteemed as medicinal health vegetable. Propagation is through seeds and cultivation is similar to that of bitter gourd. It contains higher amount of proteins, fats, carbo-hydrates and

minerals (*i.e.* iron, calcium, and vitamin c contents) Behera *et al.* (2006).

Momordica balsamina: It is a wild climber containing wide spectrum of medicinal and nutritional value. The fruits are harvested from neglected places from July to October in arid zone. It is monoecious and propagated through seeds. Fruits are small and used as vegetable. The leaves, fruits, seeds and bark of the plant contain resins, alkaloids, flavonoids, glycosides, steroids, terpenes, cardiac glycoside and saponins having various medicinal importance. The therapeutic agent is 'Momordin' which possess very good antidiabetic activity. The commercial exploitation for biopharmaceuticals and nutraceuticals are some of the prospective future potential of Jhaar karela. It is found in natural habitats of arid zone particularly neglected places. It possesses resistance against biotic and abiotic stresses which may prove worth in utilizing in the breeding programmes.

Spine gourd *(Momordica dioica)*

Momordica exist in the wild state in India and the surrounding geographical region in South and Central Asia (Hooker, 1879). Indicating that the center of origin of *M. dioica* might be in this region. It is widely cultivated in Andhra Pradesh, Orissa, Maharashtra, Bihar and West Bengal and is slowly gaining popularity as a commercial vegetable crop because of its rich taste and high nutritional value.

Kakrol is considered as an under utilized vegetable, although having significant presence of certain compounds containing higher nutritional value than many frequently consumed vegetables. It is rich in protein and vitamin C. Spine gourd fruit consists of moisture (84.1%), protein (3.1%), carbohydrate (7.7 g), fibre (3 g), and ash (1.1%). It also contains iron (4-6 mg), calcium (33 mg), phosphorus (42 mg), vitamin (A 2,700 IU), thiamine (0.05 mg), riboflavin (0.18 mg) and niacin (0.06 mg / 100 g). The fruit also contains 275.1 mg of ascorbic acid / 100 g. It has commercial importance and is exported and also used locally. The fruits are cooked with spices, fried and eaten with meat and fish (Ram *et al.*, 2004).

Little wild gourd *(Mamordica tuberosa)*

It is a weak-stemmed low herb with perennating tubers, found wild in Deccan Plateau and rain shadow areas and leeward side of Western ghats. Tender fruits are esteemed as a vegetable with medicinal properties especially as health food for diabetics. Propagation is through seeds and tubers (Joseph *et al.*, 2020).

Kaasara Kaya or Adavi Kakara *(Momordica tuberosa)* is a rare and high value hardy vegetable with medicinal and curative properties. Its versatile utility as a nutritious vegetable, folk medicine and functional food ingredient. It is naturally growing in rainfed black soils of Rayalaseema districts of Andhra Pradesh. The tubers of this wild annual vegetable sprout after the onset of monsoon and undergo dormancy during dry summer periods. Local folk harvest the tender green fruits for their own use and also supply little amount in the near by markets and generally sell them at premium price during August to October.

Snapmelon (*Cucumis melo* var. *momordica*)

Snapmelon is commonly grown as intercrop in maize. Its immature fruits are used as salad, vegetables and for other culinary preparations. Fruits at ripening stage develop suture. Its fruits are generally less sweet as compared to muskmelon; hence it is much liked by the people who are suffering sugar related disorders. Snapmelon pulp is suitable for preparation of jam by adding equal quantity of sugar to pulp. Good quality wine with excellent aroma and taste can be prepared with its pulp. It is a very popular vegetable of arid zone. It is commonly grown as a rainfed crop in Rajasthan and Gujarat.

Bitter apple *(Citrullus colocynthis)*

Bitter apple is the probable ancestor of watermelon which is bitter in taste and known as *Tumba* or 'bitter apple'. It resembles a common watermelon vine, but bears small, hard fruits with a bitter pulp. Fruit contains 15% pulp, 62% seed and 23% rind. The mesocarp contains glucose (1.3% on flesh basis). The processed mesocarp may be a good source of pectin. The juice of the fruit contains citrullin, citrullene and citrulline acid. The fruits of bitter apple also contain cucurbitacin B and its glycoside, cucurbitacin. The peel free flesh of ripe fruits contains yellow bitter oil. The seeds are used for edible purposes as well as to extract oil. Seeds contain 16.7% yellow coloured semi-dry oil rich in linoleic acid. It is one of the most drought resistant cucurbit showing maximum diversity in Thar Desert. It has been widely used in traditional medicines for centuries. Bitter apple can also be used in the preparation of biopesticide formulations.

Long melon (*Cucumis melo* var. *utilissimus*)

Long melon is popularly known as *kakri* or *Tar Kakri.* Tender fruits are delicious and used as salad, pickle and cooked as vegetable. Due to its cooling effect, it is very popular in most parts of the Thar Desert during summer. It is a warm season crop and cultivated in tropical, subtropical and milder zones of India.

Ridge gourd *(Luffa acutangula)*

Ridge gourd is an important warm season vegetable crop widely cultivated in tropical and sub-tropical parts

of India. The immature tender green fruits are cooked as vegetable. It is a good source of carbohydrates, vitamin C and minerals. Warm and humid climate is favourable for its growth and development. The Sponge gourd *(Luffa cylindrica)* tender fruits are used as vegetable which are easily digestible.

Oriental pickling melon (*Cucumis melo* var. *conomon*)

It is an annual prostrate to low trailing herb cultivated along cost and West coasts for its unripe fruits, used in several ethnic recipes and also in common vegetable preparations like sambar and aviyal.

Kachri *(Cucumis callosus)*

There are very few foraged foods that find their way into the urban markets sometimes and one of those is Kachri or Kaachri (*Cucumis callosus* or *Cucumis melo* sp.*agrestis*) that looks like miniature watermelons. The similarity to watermelons ends here and once you cut these tiny melons you see numerous seeds and very little flesh inside. The seeds impart excellent protein content to this melon along with potent antioxidants and immunity boosting properties.

Round melon *(Citrullus vulgaris* var. *fistulolus)*

Round melon is also known as round gourd, Indian squash, squash melon and Tinda. It is grown for small, tender fruits that are roughly spherical and about 5-8 cm in diameter. The fruits at cooking stage contain 1.4% protein, 1.4% fat, 3.4% carbohydrates, 1% fibre, 0.5% minerals, 13 mg carotene and 18 mg vitamin C/ 100 g of fresh weight.

Arya *(Cucumis melo* var. *chate)*

Arya is an annual plant and monoecious in nature. Tender fruits are generally used as salad and harvested before maturity. The fruit is climacteric. It is propagated by seeds. Fruit shape is long, skin colour light to dark green and smooth at tender stage. Fruit flesh is light orange at ripening without sugar and aroma. It is cultivated in several parts of arid zone.

Leafy vegetables

Traditional leafy crops are important fresh crops during the rainy season and are especially important in dried form during winter and spring seasons as a source of cheap protein. India is the home of a large number of leafy vegetables including Indian spinach *(Basella alba),* drumstick *(Moringaoleifera),* curry leaf *(Murraya koenigii), etc.* and a number of lesser known leafy vegetables, which are available seasonally and are grown in small pockets. A number of underutilized leafy vegetables which are generally used as day to day vegetables with small area of cultivation. Apart from this a number of species like *Bacopa monnieri, Boerhavia diffusa, Centella asiatica etc.* are also used as leafy vegetables basically for therapeutic value. Rural people from North-eastern parts of India prefer non-traditional vegetables like runner and petioles of *Colocasia* spp and *Xanthosoma* spp, bamboo shoots, elephant foot yam petiole, and leafy vegetables like fern shoot *(Ceratopteris),* poi *(Basella alba).* The majority of the indigenous leafy vegetables are grown in wild, semi-wild or stray conditions but are the main source of vitamins and minerals to the rural and tribal communities.

Purslane *(Portulaca oleracea)*

The plant is used as vegetable, spice and for medicinal purposes. It is annual succulent plant spreading over the surface of the land. In India, it is commonly available in summer season. It has prostrate stem with reddish yellow green colour due to presence of betalain alkaloid pigment and beta xanthins. Its stem contains white milky juice. It is succulent spongy plant and contains gum like substances.

Wild amaranth *(Amaranthus spinosus)*

Few wild species are edible and are found growing wild in most parts of India. The cultivated types are grown for nutritious grains and foliage. Its two species, *A. spinosus* and *A. viridis* are edible. They are annuals. It is easily available from June to November. In India, cultivated and wild, both species are found. *A. spinosus,* commonly known as spiny amaranth, prickly amaranth or spiny pig weed is a noxious weed in rice fields. *A. viridis,* known as slender amaranth or green amaranth is commonly found in northern part of India. In rural India, it is used as vegetable on large scale. Grain amaranth species *(A. hypochondriacus, A. caudatus, A. cruentus)* have several health benefits. They are effectively gluten free, have a variety of medically active compounds.

Crepe ginger *(Cheilocostus speciosus)*

Crepe ginger (family Cotaceae) is native to India which it has medicinal uses. It is arich source of carbohydrates and proteins. Its rhizomes and new stems are used as vegetables in the tribal areas of Chhattisgarh, Madhya Pradesh, and Jharkhand. Rhizomes are boiled with water and the same are used as vegetables. The plant has many historical uses in Ayurveda.

Nettle leaf *(Urtica dioica)*

Nettle leaf (family Urticaceae) is herbaceous perennial plant grown India. Fresh green leaves contain proteins, vitamins (A and C), iron, calcium, potassium, manganese, fat and carbohydrates. Mature leaves contain about 40% alpha linolenic acid and omega -3-fatty acid. Spring shoots (leaf tips) are consumed like

spinach. Younger tender shoots may be eaten as such or made into juice. In Uttarakhand, the plant is boiled, converted into fine pulp, cooked slowly and garnished with butter. Leaf juice mixed with water and sugar can be taken as a drink also.

Drumstick *(Moringa oleifera)*

Drumstick is widely grown buton limited scale all over India. In India, its young seeded pods and leaves are consumed as vegetables. Leaves are the most nutritious part of the plant being rich source of vitamins A, B, C and K along with manganese and protein. Leaves are cooked and used like spinach. Additionally, leaves are dried and crushed into a powder which is used in soups and sauces. Seed and pods are also a rich source of vitamin C, dietary fiber, and minerals like potassium, magnesium and manganese. Seeds sometimes removed from mature pods are eaten like peas and roasted like nuts and provide high levels of vitamin C and dietary minerals.

Sunnhemp *(Crotalaria juncea)*

Sunnhemp is a multi-purpose tropical and sub-tropical legume grown in many parts of India. It is mainly known for fibre and fodder but flowers are used as vegetables also. Flowers are rich in dietary fibre, and calcium and iron. Buds and flowers are commonly consumed as vegetables in Uttar Pradesh, Bihar and West Bengal.

Water spinach *(Ipomoea aquatica)*

Being a store house of nutrients, this leafy green vegetableis an in expensive and natural way of boosting the body 'simmunity in comparison to vitamin C supplements. Consumption of this green leafy vegetable on a regular basis boosts your body's immune system and promotes healthy development of bones. Drinking of water spinach juice is extremely beneficial for skin health as it keeps skin ever rejuvenated by eliminating harmful toxins from the body. The wide array of nutrients contained in water spinach is beneficial for hair and prevents hair loss besides improving the quality and texture of hair. In addition to the benefits discussed above, water spinach is effective in treating ulcers, menstrual pains, toothache, urination, nose bleed *etc.* It acts as a sedative for people who have insomnia or sleeping difficulty. The juice of water spinach mixed with water is used as a cold compress to treat fever. Being anti-venom, it is used to promote vomiting in case of poisoning.

Agathi/vegetable humming bird *(Sesbania grandiflora)*

It is a small legume tree vegetable grown occasionally for its leaves and flowers used as vegetable. White flowered types are preferred for vegetable and red flowered ones are more of medicinal value. Even though highly nutritious, it is bitter, the taste can be improved by precooking and draining the water and mixing with dal or other vegetables. Agathi is of South East Asian origin adapted to medium to high rainfall and sub humid to humid climates.

Chekurmanis *(Sauropus androgynus)*

Chekkurmanis is a perennial small shrubby leafy vegetable ideal as hedge. Leaves are rich in proteins, minerals and vitamins andaptly called multivitamin green. Tender leaves are of acceptable taste, non bitter, available year round and do not need any pre-cooking.

Water leaf

Water leaf also known as Ceylon spinach *(Talinum triangul are)* belonging to family Portulacaceae is a soft mucilaginous shade loving vegetable. It contains 1.3 g protein, 31 g carbohydrate, 4.3 g fat, 0.7 g fibre, 102 mg vitamin C, 1.9 g minerals, 120 mg Ca and 0.9 mg Fe / 100 g edible portion. The high oxalate content of leaves makes its consumption limited. Leaves and tender shoots are used as vegetable in soups and stews. The plant is an herbaceous perennial erect at base with succulent purple stem and triangular light green shining fleshy leaves. It is propagated through seeds and cuttings. Tender shoots can be harvested 6 to 8 weeks after planting. The yield is about 4 to 6t / ha.

Basella

Basella (Indian spinach, Malabar spinach, Malabar night shade or poi) belongs to the family Basellaceae. The green basella with dark green round to oval leaves is B. *alba* and red basella is B. *rubra*. B. *rubra* contains 1.2 g protein, 0.63 g soluble carbohydrate, 0.19 g fat, 1.55 g fibre, 113 mg vitamin C, 1.8 g minerals, 13.42 mg Ca, 6.48 mg P and 5.16 mg Fe / 100 g edible portion. The essential amino acids present include arginine, leucine, isoleucine, lysine, threonine and tryptophan. The tender shoots including leaves, leaf stalk and stem are chopped and used as vegetable. It is preferable to cook leaves in soups or stews. It contains traces of oxalic acid. Basella is used as a cooling medicine in digestive disorders and it contains antiviral substances. It is propagated by seeds or cuttings. The harvest starts after 8-10 weeks in seedlings and after six weeks in cuttings. Yield varies from 14-19.5 t / ha.

Curry leaf *(Murraya koenigii)*

Curry leaf is reported to have originated in Tarai region of Uttar Pradesh and is found in wild form along the foothills of Himalayas from Gahrwal to Sikkim, West Bengal, Assam, Western Ghats, Tamil Nadu and Kerala. The leaves are valued primarily for

seasoning and flavouring the vegetable dishes, also used in traditional medicines. It contains high amount of vitamin A, protein and fat, which makes it superior from other popular vegetables.

Horse purslane *(Punarnava)*

Horse purslane *(Boerrhavia diffusa)* belonging to family Nyctaginaceae is a diffusely branched pubescent or glabrous prostrate herb. Esteemed for its medicinal properties, the whole plant and roots are extensively used in Ayurveda. Tender leaves are cooked as spinach and have an agreeable taste. The leaves contain 2.1 g protein, 2.4 g fibre, 77.9 mg vitamin C, 82.5 mg Ca and 13.1 mg Fe / 100 g edible portion. There are two types- one with red flowers and another with white flowers. The red flowered type is used in curries and soups. It is given internally as blood purifier and to relieve muscular pain (Mini and Krishnakumary, 2004). Propagation is through seeds stem cuttings.

Ponnaganti greens *(Alternanthera sessilis)*

Ponnaganti greens *(Alternanthera sessilis)* is a small annual or perennial prostrate herb belonging to family Amaranthaceae. Several species are grown for nutritional and ornamental value. It is grown throughout the hotter parts of India. The greens contain 5 g protein, 11.6 g carbohydrate, 0.9 g fat, 2.8 g fibre, 1926 µg carotene, 17 mg vitamin C, 0.14 mg riboflavin, 1.2 mg niacin, 2.5 g minerals, 510 mg Ca, 60 mg P, 1.63 mg Fe and 46.2 mg Mg per 100 g edible portion. The leaves are variegated green and yellow or bronze and green or red and pinkish brown. The leaves are 2.5 to 7.5 cm long and are fleshy when grown in watery places. The leaves and tender shoots are clipped and used like spinach and in soups. It is propagated by cuttings and first clipping of tender leaves and stems can be done 45 to 60 days after planting.

Roselle

It is an annual herb cultivated occasionally throughout India for its tender leaves and fleshy calyx, both used as an ingredient of dhal preparations. Young seedlings and clippings are used extensively in Andhra Pradesh and Telangana as main ingredient in Gongura pickle.

Indian pennywort *(Centella asiatica)*

It is a prostrate aromatic herb with semicircular leaves on erect leaf stalks. It prefers moist wet places and propagation is through offsets. Young leaves are used in the preparation of chutneys and tonic and therapeutic food for mouth ulcer.

Chukka koora *(Rumex vesicarius)*

It is a kitchen garden vegetable cultivated occasionally in Andrhra Pradesh districts. It is an annual herb propagated through seeds. Tender leaves are harvested periodically and cooked along with dal or used in chutneys. Taste is sour.

The leaves of Rumex spp. (Polygonaceae) plants are used in traditional medicine for the treatment of severa health disorders such as infections, diarrhoea, diabetes, jaundice, oedema, hypertension, diuretic, analgesic and inflammation. It has various pharmacological activities such as antitumor, antibacterial, antiviral, antifungal, antioxidant, antiplasmodial, antinematodal and antiinflammatory activities. Antraquinones, flavonoids, stilbenoids, naphtalanes, tannins, tritepenoids, carotenoids, polysaccharides have been reported in the *Rumex* spp. It is used as a substitute for rhubarb. A decoction of the root is drunk for the treatment of rheumatism, colic, stomachache and abdominal pains caused by intestinal parasites. The leaves are used in the treatment of colic. The plant is also considered to be antidote, depurative and laxative, as well as a medicine for treating coughs and headaches (Kumar *et al.,* 2020).

Clove bean *(Ipomoea muricata)*

It is an annual weak stemmed herb, native to Teraibelt and Himalayan foothills of Nepal, but domesticated in Kerala and Karnataka as a vegetable. Tender fruits along with fleshy fruit stalk are cooked as vegetable. Propagationis through seeds. It needs staking or pandal and open areas for a good crop.

Jammi *(Prosopis cineraria)*

It grows luxuriantly under the extremely adverse agro-climate in hot arid regions and that too without much cultural care. Prosopis cineraria have multiple uses viz., nutritious rich pods, fodder and fuel, besides its favourable effects on ecology and soil fertility. It not only tolerates the extreme edapho-climatic conditions of Thar Desert but also has plentiful foliage, bears flowers and fruits during the driest period. The immature pods called as sangri are used as vegetable (Saroj and Choudary, 2020).

Yam (*Dioscorea alata*)

Dioscorea consists of about 600 species. Two species namely *D. alata* L. (larger yam, and *D. bulbifera* L. *(potato yam)* are found in Southern parts of India. Former is cultivated extensively for vegetable whereas latter is found in natural habitat. It is considered a good source of carbohydrates and used for the treatment of arthritis. Yam is consumed as raw yam, cooked soup, and powder or flour in food preparations. Yam tubers have various bio active components, namely, mucin, dioscin, dioscorin, allantoin, choline, polyphenols, diosgenin, and vitamins such as carotenoids and tocopherols. Mucilage of yam tuber contains soluble glycoprotein

and dietary fibre. Several studies have shown hypoglycemic, antimicrobial, and antioxidant activities of yam extracts (Kelmanson, 2000). Yams may stimulate the proliferation of gastric epithelial cells and enhance digestive enzyme activities in the small intestine. It has been used as a laxative and vermifuge, and in treatment for fever, gonorrhea, leprosy and tumors.

Elephant-foot yam

The elephant-foot yam is used as food in Island Southeast Asia, Mainland Southeast Asia, South Asia, New Guinea, Oceania, and Madagascar. Its origin and center of domestication was formerly considered to be India, where it is most widely utilized as a food resource in recent times.

Taro *(Colocasia esculenta)*

It is A tropical plant grown primarily for its edible corms. It Has been utilized for treatment of various ailments such As asthma, arthritis, diarrhea, neurological disorders, and Skin disorders. This crop is grown during the monsoon And both nutritive leaves with petioles and corms are Consumed as cooked vegetable. The corms are rich source Of starch whereas leaves and petioles are rich in minerals, Proteins, fats and vitamins.

Indian lotus *(Nelumbo nucifera)*

Fresh rhizomes contains moisture 83%, crude protein 2.7%, fat 0.11%, reducing sugar 1.56%, sucrose 0.41%, starch 9.25%, fiber 0.80%, Ash 1.10%, calcium 0.06%, thiamine 0.22 mg, riboflavin 0.06 mg, niacin 2.1 mg and ascorbic acid 15.0 mg. Decoction of its leave significantly reduces the serum triglyceride and cholesterol levels. Lotus has been found to have 77% antioxidant activity. Rhizome of lotus is known for its hypoglycemic, antipyretic, anti diarrheal, antibacterial and anti-inflammatory activity. The lotus seed are also quite popular as nuts and are often eaten raw. They may also be fried or dry roasted to produce a sort of popcorn.

CONCLUSION

The global diversity of vegetable crops is estimated to be around 400 species, of which about 80 species of major and minor vegetables are reported to have originated in India. These indigenous and minor vegetables are primary candidates for greater use of crop biodiversity in horticulture as they are consumed locally and can be produced profitably in both rural and urban environments.

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Evaluation of ethyl oleate and potassium carbonate in drying on vine methodology of raisin making under tropical conditions of India

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ABSTRACT

Different levels of ethyl oleate and potassium carbonate were tried to produce raisins by following DOV method. The application of ethyl oleate and potassium carbonate is found suitable for faster drying of grapes (*Vitis virifera* L.) in DOV method and able to produce quality raisins. However, application of solution (15 ml ethyl oleate and 25g potassium carbonate in 1L water) on first day and on 4th day (11 ml ethyl oleate and 18 g potassium carbonate in 1L water) was found most effective than other treatments. Further, studies on canopy management, load management and refinement of other agro-techniques are needed to obtain quality raisins by adopting DOV under tropical conditions of India.

Key Words: DOV, Grape drying, Browning, Storage, Sensory properties

Under Indian conditions, Australian method of grape drying where grape bunches are pretreated with solution of ethyl oleate and potassium carbonate before drying is widely adopted (Adsule *et al.* 2012). Quality of raisins is largely affected by drying conditions. Prevailing weather conditions like temperature, relative humidity and wind velocity affect drying rate of grapes and decide the colour of raisins (Sharma *et al.*, 2016). However, grape growers are practicing various combinations of ethyl oleate and potassium carbonate with different dipping durations to produce raisins which are widely accepted by consumers. Natural sun drying and DOV method of grape drying are very rarely tried. No scientific data are available on quality of produce when grapes are dried on vine. In India, maximum vineyards are on Y trellises and DOV is found suitable for Y trellises also. To generate the data on drying behaviour and raisin quality on experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at ICAR-NRC for Grapes, Pune, during 2017. The treatments were imposed on bunches of 5 year old vines of Thompson Seedless grown on Dogridge rootstock. The vines were spaced on 10×6 ft distance. Two prunings and single crop system was followed and fruit pruning was performed during 3rd week of October 2016. In each treatment, canes of targeted bunches were tied on trellis structure and cut was made 3-4 buds above base. Treatments were imposed when TSS content in berries reached more than 22°brix.

Five treatments namely cut made on canes and left for drying (T_1), one spray of solution (15 ml ethyl oleate and 25g potassium carbonate in 1L water) on first day (T_2), in T_3 solution (15 ml ethyl oleate and 25 g potassium carbonate in 1L water) was sprayed on first day and second spray was done on 4th day (11 ml ethyl oleate and 18 g potassium carbonate in 1L water), one spray of solution (15 ml ethyl oleate and 25 g potassium carbonate in 1L water) on fourth day of drying (T_4) and in T_5 solution (15 ml EO and 25g P15 ml ethyl oleate and 25 g potassium carbonate in 1L water C) was sprayed on first day and second spray (11 ml ethyl oleate and 18 g potassium carbonate in 1L water was performed on 6th day of drying. Each treatment was imposed on twenty bunches and each treatment was replicated 5 times. Treatments were imposed according to randomized block design.

The samples were collected per day to estimate moisture percentage. The bunches were untied and separated from trellis when moisture level in raisins was reached below 16%. Prepared raisins were separated, collected, packed and storage for further

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studies. For storage study, the raisins were packed in LDPE pouches and stored at temperature of 10°C for 3 months.

The moisture contents (in percentage) in the samples were measured using Moisture Analyzer of LCGC (Model Axis). Browning index was recorded by UV-VIS spectrophotometer at 420 nm. Colour intensity was determined by taking absorbance at 420, 520 and 620 nm by using UV-VIS spectrophotometer (UV-harmaspecv 1700, Shimadzu) as per method suggested by Somers and Evans (1977). Observations on wrinkle uniformity and shape uniformity were recorded based on visual observation. A randomly collected lot of 20 raisins was considered to generate data on wrinkle and shape uniformity.

Sensory studies were performed by a sensory panel comprising of 10 persons having basic knowledge and training on organoleptic studies of raisins. The panellists were having experience of raisin tasting. The sensory attributes were colour, texture, flavor, mouth feel, taste and overall acceptability. Raisins from all treatments were evaluated based on 9-point Hedonic scale (9-like extremely, 8-like very much, 7-like moderate, 6-like slightly, 5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely). The generated data were analysed by using SAS software.

RESULTS AND DISCUSSION

The significant differences were noted among the treatments for recorded parameters. Maximum days (18.40) were recorded in T_1 (Table 1). Application of different combinations of ethyl olete and potassium carbonate in the process of DOV, reduced days required to achieve less than 16% moisture in raisins. Least days (only 9.60) were observed in T_3 followed by T_5 and T_2. Data on browning index and colour intensity showed that T_3 produced raisins with minimum browning and colour intensity while maximum values were recorded in T_1 where no application of ethyl oleate and potassium carbonate was not applied. It is noted by various researchers that application of oleic acid and potassium carbonate solutions results in faster grape drying than the untreated grapes. Untreated bunches taken maximum days while ethyl oleate and potassium carbonate accelerated water losses and resulted in faster drying.

Application of oleic acid destroys the resistance of waxy layer which prevents moisture transfer and increased the drying rate. Commercially adopted cold dipping methods utilize a combination of potassium carbonate and ethyl esters of fatty acids (commonly known as ethyl oleate). Cold dipping treatments enhance water loss rate two to three folds. It has become common practice in various grape growing countries where drying conditions are very unpredictable. The type of chemical pre-treatment and origin of the product affect the drying behavior of the grapes significantly.

The application of ethyl oleate as pre-treatment solution results in faster grape drying which leads to better colour of raisins (Sharma *et al.* 2013). Colour homogeneity in raisins was affected when alkaline emulsion of ethyl oleate was applied in the DOV process of raisin making (Venkatram *et al.* 2017). Same observations are recorded in present study. Application of ethyl oleate and potassium carbonate resulted in faster grape drying and produced raisins with lower colour intensity and brown index than T_1 where bunches did not receive any treatment.

Consumer preference also influenced by uniformity of wrinkles on raisins and shape uniformity. More uniformity in wrinkles and shape of raisins were observed in treatments where ethyl oleate and potassium carbonate applications were given to bunches (Table 2). While lesser uniformity was recorded raisins where no application was given to bunches which were under drying by adopting DOV. Significant differences were noted among the treatments. Parpinello *et al.* (2012) stated that the finer wrinkle and

Table 1. Effect of treatments on raisin quality under DOV methodology of grape drying

Treatment	Days to achieve less than16% moisture	Browning index (%)	Colour intensity (%)
T_1	18.40	4.91	9.09
T_2	11.40	2.76	6.29
T_3	9.60	2.12	4.80
T_4	12.60	2.96	5.54
T_5	10.80	2.45	5.29
LSD (5%)	1.334	0.600	0.659
SEM±	0.629	0.283	0.311

Table 2. Effect of ethyl oleate and potassium carbonate combinations with DOV on wrinkle and shape uniformity of raisins

Treatment	Wrinkle uniformity (%)	Shape uniformity (%)
T_1	19.6	18.4
T_2	38.2	37.2
T_3	72.6	69.2
T_4	58.8	55.4
T_5	48.6	46.8
LSD (5%)	5.225	5.564
SEM±	2.464	2.624

a more compact shape of raisins are desirable qualities for raisins and better raisin quality produced by DOV system. DOV raisin shows the lower values abut defects compared with structure, gravel and plastic drying methods (Espíndola *et al.* 2019).

Effect of ethyl oletae and potassium carbonate applications during DOV process on sensory properties. It is clear from figure that the T_1 obtained minimum scores for mentioned parameters while acceptance levels of raisins were higher in treated bunches. Maximum values were recorded in T_3. Variations among the treatments were due to different levels of ethyl oleate and potassium carbonate and time of applications. Sharma *et al.* (2017) also recorded variations in score of sensory parameters of raisins prepared by differences in combinations of ethyl oleate and potassium carbonate and application timings when raisins were prepared by applications of commercial dipping oil and ethyl oleate and potassium carbonate.

After preparation raisins are stored and as per demand and marketing strategies raisins are supplied. Generally, consumers get stored raisins. Hence, visual and sensory quality of raisins after storage plays an important role. Significant differences were observed among the treatments but values were higher in stored raisins in comparison to values noted before storage. Trends of data were almost same which was noted for same parameters before storage.

The T_3 showed superiority over other treatments while T_1 where solution was not spray was noted with maximum values of browning as well as colour intensity. Color is a main qualitative feature of dried fruits and it changes during storage due to some chemical and biochemical reactions. Low temperature storages recommended for raisins. Sharma *et al.* (2017) observed increased colour intensity and browning index in raisins during storage at low temperature and same observations were recorded in present study also.

Sensory parameters of stored raisins were in same manner in which observed before storage. Thus, it is found that application of ethyl oleate and potassium carbonate is found suitable for faster drying of grapes in DOV method. However, application of solution (15 ml ethyl oleate and 25 g potassium carbonate in 1L water) on first day and second spray on 4th day (11 ml ethyl oleate and 18 g potassium carbonate in 1L water) was found most effective than other treatments. In continuation of present study refinements on agro-techniques are also needed to adopt DOV for raisin making in Indian conditions.

Grape drying on vine (DOV) is found suitable under tropical conditions of India where maximum temperature of 35-38°C coupled with low humidity of (10-15%) coincide with grape drying period (February and March). Applications of solution (15 ml ethyl oleate and 25 g potassium carbonate in 1L water) on first day and on 4th day (11 ml ethyl oleate and 18 g potassium carbonate in 1L water) was found most effective than other treatments in obtaining better dried grape quality with faster drying.

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Tree storage of Nagpur mandarin *(Citrus reticulata)* fruits by managing incidence of creasing disorder in central India

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ABSTRACT

An experiment was conducted to improve the yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco) at ICAR-CCRI, Nagpur, during 2020.The pre-harvest foliar application of 20 or 25 ppm of GA_3 along with 1.5% urea delays the senescence of tissues and makes albedo tissues compact which helps in increasing the yield by delayed harvesting, improving the quality of fruits by maintaining their firmness. The yield and yield attributes, *viz.* maximum yield per plant and total estimated yield per hectare was noted in GA_3 20 ppm + urea 1.5% (130.73 kg/plant and 36.21t/ha) in *ambia bahar* and in GA_3 25 ppm + urea 1.5% (82.48 kg/plant and 22.84 t/ha) in *mrig bahar*. Minimum number of creased fruits recorded in GA_3 25 ppm + urea 1.5%in both the seasons (38 in *ambia bahar* and 19 in *mrig bahar*). Maximum fruit firmness (2.33 kg/cm^2) recorded in GA_3 25 ppm + urea 1.5% in *ambia bahar* and in GA_3 20 ppm + urea 1.5% (2.65 kg/cm^2) in *mrig bahar* indicating fruits are less matured compared to other treatments. Fruit physical characteristics, *viz*. maximum fruit weight and volume were recorded in GA_3 20 ppm + urea 1.5% (162.70 g and 159.50 cm^3 respectively) in *ambia bahar* and in GA_3 25 ppm + urea 1.5% (146.25g and 144.00 cm^3 respectively) in *mrig bahar* over the control. The biochemical characteristics, *viz.* highest TSS was recorded in the control in both *ambia* and *mrig bahar* (10.10% and 11.97% respectively) indicating that fruits were ripen earlier compared to the fruits of other treatments, whereas lowest TSS (8.92%) was recorded in GA_3 20 ppm + urea 1.5% in *ambia bahar* and in GA_3 25 ppm + urea 1.5% (9.92%) in *mrig bahar* shown delayed ripening of the fruits. Maximum acidity was noted in GA_3 25 ppm + urea 1.5% in both *ambia* and *mrig bahar* (0.89% and 0.84% respectively) compared to other treatments.

Key Words: Tree storage, Incidence, Disorder, Albedo, Cracks

In central India, mainly two types of Nagpur mandarin (*Citrus reticulata* Blanco) crops are taken, *viz*. spring blossom *(ambia)* and monsoon blossom *(mrig)* with harvesting in October-December and February-April respectively. To get good market values and profit, some growers of Nagpur mandarin go for the late harvesting by storing fruits on trees only, but there is the incidence of physiological disorder due to late harvesting. These fruits have poor post-harvest storage capacity and transportability due to decreased firmness. Creasing disorder is also known as puffiness or albedo breakdown. This disorder is characterised by presence of cracks in cell layers of albedo tissue of peel, depressions on rind and healthy areas of fruit becomes bulky with loss of turgor pressure, cell wall collapse, pectin degradation and promotion of pectin methyl esterase activity of albedo tissue. Cultural practices (mineral nutrition), climatic (light, temperature, humidity), genetic and endogenous factors crease disorder (Li Juan and Chen Jiezhong, 2017; Sallato *et al.*, 2017). The combination of fruit thinning and GA_3 application, sufficient nutrition application (Ca, K, and P) and consistent irrigation reduce fruit creasing incidence(Cronje *et al.*, 2013). Therefore, an experiment was conducted.

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MATERIALS AND METHODS

The selected orchards were 12 years old spaced at 6 m × 6 m. The treatments were replicated four times in a Randomized block design. The yield, quality and

other characteristics were recorded according to the treatments. The fruits were collected at maturity in January 2021 for *ambia* crop and in March 2021 for *mrig* crop and subjected to physico-chemical analysis. Different concentrations of gibberellic acid (GA_3), *viz.* 10, 15, 20 and 25 ppm along with 1.5% urea are foliar applied to delay the harvesting at monthly intervals from October-December in *ambia bahar* and November-December in *mrig bahar*.

RESULTS AND DISCUSSION

The treatments found no effect on number of harvested fruits / plant in *ambia bahar*, but maximum number of harvested fruits / plant were recorded in treatment GA_3 25 ppm + urea 1.5%in *mrig bahar*. The maximum yield / plant and total estimated yield / hectare were noted in GA_3 20 ppm + urea 1.5% (130.73kg / plant and 36.21t / ha) in *ambia bahar* and in the treatment GA_3 25 ppm + urea 1.5% (82.48 kg / plant and 22.84 t / ha) in *mrig bahar*. The delayed harvesting increased number of marketable fruits / plant by decreasing the number of creased fruits / plant due to delayed maturity in treated plants and similar results of increased yield and yield attributes in gibberellic acid treated plants noted by Jagtap *et al.* (2013), Jain *et al.* (2015), Bhatt *et al.*, 2016, Gurung *et al.*, 2016, Ennab, 2017.

Minimum number of creased fruits were recorded in GA_3 25 ppm + urea 1.5% both in *ambia* and *mrig bahar* (38 and 19 respectively), whereas maximum number of creased fruits (62 and 45 respectively) were recorded in the control (Table 1). Thus, GA_3 application on Nagpur mandarin has significant effect on delaying maturity of fruits, and by reducing the number of creased fruits. The treatments shown significant results for fruit firmness, indicating that treatments have significant effect on ripening behaviour of fruits. Minimum fruit firmness recorded in control both in *ambia* and *mrig bahar* (1.31 and 1.65 kg / cm^2 respectively), indicating fruits are ripen with maximum firmness (2.33 kg / cm^2) in GA_3 25 ppm + urea 1.5% in *ambia bahar* and in GA_3 20 ppm + urea 1.5% (2.65 kg / cm^2) in *mrigbahar*. Gibberellin application keeps the albedo tissues compact, delays the senescence of tissues, maintains higher protein content in peel, lowers the incorporation of amino acids to proteins. Thus, gibberellic acid application reduced the number of creased fruits and maintains fruit firmness by delayed maturity (Greenberg *et al.*, 2010).

Maximum fruit weight and fruit volume were recorded in treatment GA_3 20 ppm + urea 1.5% (162.70g and 159.50 cm^3 respectively) in *ambia bahar* and in GA_3 25 ppm + urea 1.5% (146.25g and 144.00 cm^3 respectively) in *mrig bahar* over the control (140.50 g

Table 1. Effect of different concentrations of GA_3 on yield and fruit physico-chemical characteristics in *ambia* and *mrig bahar* of Nagpur mandarin at ICAR-CCRI, Nagpur

Treatment	*ambia bahar*													*mrig bahar*										
	No of fruits harvested/ plant	Yield (kg/ plant)	Yield (t/ha)	No of creased fruits/plant	Fruit firmness (kg/cm^2)	Fruit wt. (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit volume (cm^3)	Juice (%)	TSS (%)	Acidity (%)	TSS/ Acid ratio	Vit C (mg/l 00 ml)	No of fruits harvested/ plant	Yield (kg/ plant)	Yield (t/ha)	No of creased fruits/ plant	Fruit firmness (kg/cm^2)	Fruit wt. (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit volume (cm^3)	Juice (%)	TSS (%)	Acidity (%)	TSS/ Acid ratio	Vit C (mg/l 0 ml)
$GA_3$10 ppm + urea 1.5%	774	122.92	34.05	53	1.78	158.80	62.12	69.03	155.50	45.18	9.15	0.67	13.61	33.85	517	71.09	19.69	35	1.70	137.25	57.85	67.66	135.00	45.17	10.42	0.80	13.05	33.25
$GA_3$15 ppm + urea 1.5%	787	123.50	34.21	47	2.05	156.85	61.65	69.67	154.50	45.91	9.00	0.84	10.78	34.00	531	75.40	20.88	31	2.26	142.00	53.12	65.27	139.75	46.02	10.35	0.80	12.85	33.50
$GA_3$20 ppm + urea 1.5%	803	130.73	36.21	45	2.16	162.70	62.69	69.78	159.50	46.56	8.92	0.72	12.46	34.75	547	78.79	21.82	29	2.65	143.75	58.13	65.47	141.50	46.32	9.95	0.81	12.21	35.00
$GA_3$25 ppm + urea 1.5%	800	122.97	34.06	38	2.33	153.30	63.48	70.16	150.00	49.93	9.47	0.89	10.56	36.13	564	82.48	22.84	19	2.36	146.25	59.10	66.90	144.00	46.83	9.92	0.84	12.17	35.50
Control	766	107.60	29.80	62	1.31	140.50	54.73	66.14	137.25	40.37	10.10	0.75	13.50	32.25	476	62.55	17.32	45	1.65	131.25	52.78	60.45	129.00	40.96	11.97	0.75	15.01	31.50
C.D.	NS	10.29	2.85	4.41	0.20	5.40	3.07	2.14	5.35	3.15	0.20	0.14	2.21	2.33	50.53	9.83	2.72	6.98	0.27	9.93	3.38	3.64	9.93	2.79	0.54	0.04	1.05	1.84
SE(m)	16.23	3.30	0.91	1.41	0.06	1.73	0.98	0.68	1.72	1.01	0.06	0.04	0.71	0.75	16.22	3.15	0.87	2.24	0.08	3.18	1.08	1.17	3.18	0.89	0.17	0.01	0.33	0.59

and 137.25 cm^3 in *ambia bahar*, 131.25 g and129.00 cm^3 in *mrig bahar*).

The treatment GA_3 25 ppm + urea 1.5% recorded maximum fruit length (63.48 mm in *ambia* and 59.10 mm in *mrig bahar*) and breadth (70.16 mm) in *ambia bahar* and 67.66 mm breadth recorded in GA_3 10 ppm + urea 1.5% in *mrig bahar* over the control. The treatment GA_3 25 ppm + urea 1.5% recorded the maximum juice per centin both *ambia* and *mrig bahar* (49.93% and 46.32% respectively) whereas minimum juice (40.37% and 40.96% respectively) was recorded in the control.

The total soluble solids, acidity, TSS / Acid ratio and vitamin C content of fruits found statistically significant for both seasons. The highest TSS was recorded in the control in both *ambia* and *mrigbahar* (10.10% and 11.97% respectively), indicating that fruits ripen earlier compared to the other treatments, whereas lowest TSS (8.92%) was recorded in GA_3 20 ppm + urea 1.5% in *ambia bahar* and GA_3 25 ppm + urea 1.5% (9.92%) in *mrigbahar* shows delayed ripening of the fruits.

The maximum acidity was recorded in GA_3 25 ppm + urea 1.5% in both *ambia* and *mrig bahar* (0.89% and 0.84% respectively), whereas minimum acidity (0.67%) was recorded in GA_3 15 ppm + urea 1.5% in *ambia bahar* and in the control (0.75%) in *mrig bahar*. Minimum TSS / acid ratio was recorded in GA_3 25 ppm + urea 1.5% (10.56 and 12.17 respectively) in both the seasons, indicating that fruits matured but not ripen as compared to other treatments and maximum in GA_3 10 ppm + urea 1.5% (13.61) in *ambia bahar* and in control (15.01) in *mrig bahar*. Significantly maximum vitamin C content was recorded in GA_3 25 ppm + urea 1.5% (36.13 and 35.50 mg / 100ml), followed by GA_3 20 ppm + urea 1.5% (34.75 and 35.00 mg / 100 ml) compared to the control (32.25 and 31.50 mg / 100 ml) in both the seasons. Physico-chemical analysis of Nagpur mandarin during holding of fruit on the tree were noted by Similar results of increased fruit quality characteristics were also reported by Debaje *et al.* (2011), Jagtap *et al.* (2013), Jain *et al.* (2015), Rokaya *et al.* (2016) and Reddy *et al.* (2022).

CONCLUSION

Storage of Nagpur mandarin fruits on trees by pre-harvest application of GA_3 has significant effect on delaying the maturity and maintaining fruit firmness. Foliar application of 20 or 25 ppm of GA_3 along with 1.5% urea delays the senescence of tissues and makes albedo tissues compact, thus reduce the albedo breakdown or creasing incidence during tree storage of Nagpur mandarin fruits by improving the quality characteristics of fruits even at delayed harvesting.

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Characterizing yield, nutrient elimination and fruit quality analysis of custard apple *(Annona squamosa)* under consortium of *Azospirillum brasilense* and vermicompost

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ABSTRACT

The experiment was conducted to find out the effect of *Azospirillum* and vermicompost through application of different treatment combinations on eight years old bearing grafted plants of custard apple cv. Raydurg during 2018-2019. The results revealed that T_{10} (AZS @ 50 g + V.C. @ 10 kg/plant) was found optimally better in improvement of morphometric attributes. The application of (AZS @ 50 g + V.C. @ 10 kg/plant) in T_{10} treatment resulted in better crop at low inputs-use efficiency without having adverse effect on environment and offers an alternative for organic cultivation involving bioinnoculants. The studies harness the role of organic inputs along with *AZS* in optimization of fruit yield and maintenance of soil health parameters for efficient utilization of natural resources.

Key Words: *Azospirillum brasilense*, Vermicompost, Fruit set, Fruit weight, Nutrients

Custard apple (*Annona squamosa* L.) belongs to family Annonaceae. Vermicompost is an eco-friendly supportive organic additive derived from biodegradable organic wastes by earthworms and microorganisms especially *Eisenia fetida* (Sharma *et al.*, 2013). Vermicompost is devoid from chemical inputs and rich in supporting useful micro - flora such as N fixers, P-solubilizers, cellulose decomposing micro-flora *etc.* Vermicompost improves better water-holding capacity and thus prevents soil erosion (Verma *et al.*, 2013). It also improves mineral nutrient content of soil in terms of macro and micronutrients; vermicompost has very high porosity, aeration, drainage and water-holding capacity (Kumar *et al.*, 2011). Hence, an experiment was conducted to find out the effect of *Azospirillum* and vermicompost on yield, nutrient elimination and fruit quality analysis of custard apple cv. Raydurg.

MATERIALS AND METHODS

The experiment was conducted at College of Horticulture and Forestry, Jhalawar, during 2018-19 and 2019-20. The field experiment was laid out in Randomized Block Design (RBD) with three replications. Eight years old custard apple cv. Raydurg plants of uniform size, growth and vigour were selected. A total of 48 plants were selected. Experiment comprising sixteen treatments, *viz.*, T_0(control), T_1(AZS@ 25 g/plant), T_2(AZS@ 50 g/plant), T_3(AZS @ 75 g/plant), T_4(V.C. @ 10 kg/plant), T_5(V.C. @ 15 kg/plant), T_6(V.C. @ 20 kg/plant), T_7(AZS @ 25 g + V.C. @ 10 kg/plant), T_8(AZS @ 25 g + V.C. @ 15 kg/plant), T_9(AZS @ 25 g + V.C. @ 20 kg/plant), T_{10}(AZS @ 50 g + V.C. @ 10 kg/plant), T_{11}(AZS @ 50 g + V.C. @ 15 kg/plant), T_{12}(AZS @ 50 g + V.C. @ 20 kg/plant), T_{13}(AZS @ 75g + V.C. @ 10 kg/plant), T_{14}(AZS @ 75g + V.C. @ 15 kg/plant) and T_{15}(AZS @ 75g + V.C. @ 20 kg/plant).

Observations were recorded on various methods used for studying yield and quality attributes of custard apple cv. Raydurg are including as well as numbers of female flowers on selected treated plants were recorded visually from initiation of first flowering till the completion of full bloom during consecutive seasons and the average was worked out. The number of fruits/plant was counted just before harvesting. Fruit set per cent was calculated by using the formula of (% fruit set = number of fruit set/number of flowers cluster × 100) given by (Westwood *et al.*, 1983). The number of fruits/

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plant was counted under treated plant in each treatment and was harvested at horticultural maturity and expressed as number fruits / tree.

For computing the yield of fruits per plant, matured fruits were harvested and weighed periodically and yield was expressed in kg per tree. The yield per hectare (q) was calculated by multiplying the value of yield / tree (kg) by total number of plants / ha and dividing the result by 1000. Fruit weight (g) was calculated by dividing the weight of fruits with number of fruits weighed.

The pulp weight five fruits were harvested at horticultural maturity fruits from each treatment combinations were extracted and then weighed by electronic balance and the average was worked out. Pulp percentage was calculated after estimation of pulp weight and fruit weight under different treatment combinations and the pulp percentage of fruit was calculated by formula pulp weight / fruit weight × 100. Fruit diameter transversely with the help of Vernier Calipers, mean value per fruit calculated and expressed in millimeters.

The numbers of visible prominent areoles were counted visually from outer exocarp on five ripened fruits and average number of areoles was worked out. The average nutrient composition of macro nutrients available in custard apple fruit after analysis of representative fruit samples through standard drying in muffle furnace at 102°C and following analytical procedures (colorimetric method) are represented (Table 1). The average estimation of N, P and K content in fruits was taken as the basis for calculation of macro-nutrient removal under different treatment combinations on the basis of yield obtained through differential treatments (Table 1). The data were subjected to individual year analysis by using Fisher's (1950) analysis of variance technique. The significance of treatments was tested through F test at 5 per cent level of significance.

RESULTS AND DISCUSSION

The maximum number of female flowers / branch, fruit set (%), number of fruits / plant, yield / plant (kg) and yield / ha was recorded with T_{15} treatment (AZS @ 75 g + V.C. @ 20 kg / plant), considering the lower input use of *Azospirillum* and vermicompost in T_{10} treatment (AZS @ 50 g + V.C. @ 10 kg / plant) and the equivalence with regard to most of the yield attributes includes as number of female flowers / branch (249.67), fruit set (43.95%), number of fruits / plant (109.67), yield / plant (24.57 kg) and yield / ha (98.30 q) were recorded with T_{10} treatment (AZS @ 50 g + V.C. @ 10 kg / plant) which was found to be at par with T_{15} treatment, therefore T_{10} treatment was considered better as compared with T_{15} treatment (Table 1).

It could be attributed to better availability of mineral nutrients as like N, P, K, Fe, Mn, Cu and Zn due to application of organic matter through vermicompost which might augmented the uptake of macro and micro-nutrients along with the synthesis of

Table 1. Nutrient removal by custard apple cv. raydurg in response to treatment combinations of *Azospirillum* and vermicompost on the basis of yield obtained under different treatment combinations

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	Yield (kg/ha)
T_0 (control)	0.16	0.01	0.23	62.79
T_1 (AZS @ 25 g/plant)	0.21	0.01	0.30	80.97
T_2 (AZS @ 50 g/plant)	0.21	0.01	0.30	81.77
T_3 (AZS @75 g/plant)	0.22	0.01	0.31	82.78
T_4 (V.C.@ 10 kg/plant)	0.21	0.01	0.30	81.91
T_5 (V.C. @ 15 kg/plant)	0.22	0.01	0.31	84.70
T_6 (V.C. @ 20 kg/plant)	0.22	0.01	0.31	84.49
T_7 (AZS @ 25 g + V.C.@ 10 kg/plant)	0.22	0.01	0.31	85.39
T_8 (AZS @ 25 g + V.C.@ 15 kg/plant)	0.22	0.01	0.31	85.38
T_9 (AZS @ 25g + V.C.@ 20 kg/plant)	0.22	0.01	0.31	85.46
T_{10} (AZS @ 50 g + V.C. @ 10 kg/plant)	0.25	0.01	0.36	98.30
T_{11} (AZS @ 50 g + V.C.@ 15 kg/plant)	0.25	0.01	0.36	98.35
T_{12} (AZS @ 50 g + V.C.@ 20 kg/plant)	0.25	0.01	0.36	97.67
T_{13} (AZS @ 75g + V.C.@10 kg/plant)	0.25	0.01	0.36	98.59
T_{14} (AZS @ 75 g + V.C.@ 15 kg/plant)	0.28	0.01	0.39	103.62
T_{15} (AZS @ 75 g + V.C.@ 20 kg/plant)	0.25	0.02	0.36	98.09

*AZS, *Azospirillum brasilense*; *V.C., vermicompost

greater amounts of auxins. The better effect of T_{10} treatment (AZS @ 50 g + V.C. @ 10 kg/plant) in improvement of fruit set and the yield parameters may also be described behind the fact that *Azospirillum* might enhanced the activity of beneficial soil microbes which increased the translocation of metabolites from roots to flower and perhaps augmented the pollen germination and pollen tube growth there by resulting in augmented fruit set.

These findings are in line with (Lal and Dalal, 2014). Nitrogen has main effects on fruiting because it resulted in more flowering sites and reduced the abortion of female flowers which enhanced the number of fruits (Herencia *et al.*, 2011) and (Changotra *et al.*, 2017) in their experiment also reported the positive effects of vermicompost. These minimum values were recorded with T_1 (control).

The data reflects average nutrient percentage of dry material fruit analysis of custard apple cv. Raydurg. The nutrient removal (N, P, K) in kg/ha on the basis of final yield obtained under custard apple cv. Raydurg plants in response to various treatment combinations of *Azospirillum* and vermicompost. The treatments T_{10} to T_{15} were found at par in removal of maximum N and K content under allotted treatment combinations; however, P removal did not exhibit any significant difference under various treatment effects.

The treatment effects under present studies reveal that there was maximum nutrient removal of K, followed by N and P under present studies. The studies revealed that potassium plays immense role in imparting fruit hardiness and nutritional enrichment to custard apple.

The maximum fruit weight (g), pulp weight (g), pulp (%), number of areoles/fruit, horizontal fruit diameter (mm) and vertical fruit diameter (mm), were recorded with T_{15} treatment (AZS @ 75 g + V.C. @ 20 kg/plant) (Table 2). However, T_{15} treatment was found at par with T_{10} treatment (AZS @ 50 g + V.C. @ 10 kg/plant) in equivalence with regard to most of physico-chemical parameters as well as fruit weight (223.3 g), pulp weight (112.50 g), pulp (50.21%), number of areoles/fruit (93.83), horizontal fruit diameter (89.95 mm) and vertical fruit diameter (93.33 mm), fruit quality obtained best under T_{10} treatment which was at par with T_{15} treatment, therefore T_{10} treatment was considered better as compared with T_{15} treatment.

Table 2. Effect of *Azospirillum* and vermicompost on fruit weight, pulp weight, pulp, number of areoles/fruit, horizontal and vertical fruit diameter of custard apple cv. Raydurg pooled analysis for two consecutive seasons during (2018 and 2019)

Treatment	Fruit weight (g)	Pulp weight (g)	Pulp (%)	Number of areoles/ fruit	Horizontal fruit diameter (mm)	Vertical fruit diameter (mm)
T_0 (control)	206.50	82.00	39.69	82.00	75.75	76.75
T_1 (AZS @ 25 g/plant)	212.50	93.00	43.93	85.00	82.65	84.15
T_2 (AZS @ 50 g/plant)	214.17	95.83	44.66	85.00	82.86	83.47
T_3 (AZS @75 g/plant)	213.50	96.83	45.24	86.17	83.03	84.70
T_4 (V.C.@ 10 kg/plant)	215.33	97.17	45.04	86.50	83.99	85.26
T_5 (V.C. @ 15 kg/plant)	215.50	96.83	44.83	87.00	84.46	85.86
T_6 (V.C. @ 20 kg/plant)	214.17	97.17	45.28	88.33	84.03	86.12
T_7 (AZS @ 25 g +V.C.@ 10 kg/plant)	215.00	98.33	45.67	88.00	82.99	86.89
T_8 (AZS @ 25 g + V.C.@ 15 kg/plant)	216.50	98.33	45.55	87.17	84.59	87.06
T_9 (AZS @ 25g + V.C.@ 20 kg/plant)	215.17	99.00	45.90	88.00	84.66	85.87
T_{10} (AZS @ 50 g + V.C. @ 10 kg/plant)	223.83	112.50	50.21	93.83	89.95	93.33
T_{11} (AZS @ 50 g + V.C.@ 15 kg/plant)	224.17	112.50	50.16	93.67	90.87	93.43
T_{12} (AZS @ 50 g + V.C.@ 20 kg/plant)	223.83	113.17	50.53	94.00	90.30	93.24
T_{13} (AZS @ 75g + V.C.@10 kg/plant)	224.17	112.50	50.12	93.83	90.17	94.27
T_{14} (AZS @ 75 g + V.C.@ 15 kg/plant)	227.17	117.50	51.63	96.33	93.73	96.52
T_{15} (AZS @ 75 g + V.C.@ 20 kg/plant)	224.00	112.83	50.33	94.33	89.82	94.12
SEm (±)	1.35	1.42	0.92	1.26	1.74	1.57
CD. (0.05%)	S	S	S	S	S	S
CV (%)	5.93	7.03	3.00	5.30	5.83	5.70

*AZS, *Azospirillum brasilense;* *V.C., vermicompost

The augmentation in biochemical parameters of custard apple cv. Raydurg fruits in T_{10} treatment may also be explained with the support of the fact that *Azospirillum* application in conjunction with vermicompost could possibly enhanced nitrogen fixation and uptake of nitrogen thereby stimulating the catalytic number of enzymes in the physiological process and might increase cumulative production of sugars and amino acids that ultimately enhanced the fruit weight, pulp weight, pulp (%), number of areoles / fruit, horizontal fruit diameter and vertical fruit diameter.

The improved fruit quality might be attributed to better vegetative growth of the treated plants, which resulted in maximum amounts of photosynthesis (starch, carbohydrates) and the translocation to the fruits (Changotra *et al.,* 2017). These results are confirmed by (Gupta *et al.,* 2012), (Singh *et al.,* 2012) and (Dadashpour *et al.,* 2012). Vermicompost augmented the nitrogen, phosphorous and potassium levels which promotes sugars accumulation in berries and balanced of N, P and K is important for appropriate availability of those nutrients to strawberry plants (Yadav *et al.,* 2012). These minimum values were recorded with T_1 (control).

CONCLUSION

It is concluded that combined application of (AZS @ 50 g + V.C. @ 10 kg / plant) was found comparatively better over all other treatments with respect to improvement of physico-chemical fruit quality parameters of custard apple cv. Raydurg plants. The present studies harness the role of organic inputs along with bio-inoculant *Azospirillum* in optimization of fruit yield and maintenance of soil health for efficient utilization of natural resources.

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Effect of time of grafting and scion varieties on success of graftage in guava *(Psidium guajava)*

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ABSTRACT

The experiment was conducted at College of Horticulture and Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi, during 2019-20 to see the effect of time of grafting and source of scion on grafting performance in guava (*Psidium guajava* L.). Treatments comprised four time of grafting, *viz.* T_1: 1st fortnight of January, T_2: 2nd fortnight of January, T_3: 1st fortnight of February and T_4: 2nd fortnight of February, and four different scion varieties *viz.* S_1: Allahabad Safeda, S_2: L-49, S_3: Lalit and S_4: Shweta. Significant differences of time of grafting and source of scion were observed in different grafting and growth parameters. The maximum bud sprouting (97.8%) was noted in T_2S_2, 2nd fortnight of January + L-49, which found at par with T_4S_1, 2nd fort night of February + Allahabad Safeda (95.6%), whereas minimum bud sprouting was noted in T_1S_4 1st fortnight of January + Shweta (53.3%). The highest final survival (95.6%) obtained from T_2S_2 (2nd fortnight of January + L-49) which was at par with T_3S_1 and T_3S_2, whereas lowest final survival was observed in 1st fortnight of January + Shweta (53.3%).

Key Words: Time of grafting, Scion, Wedge grafting, Bud sprouting, Seedlings

Guava (*Psidium guajava* L.) is well known tropical fruit tree.Non-availability of quality planting material and consequent substitution of poor-quality seedling have adversely affected its production and productivity. High-density planting in guava has emerged as a boon and farmers are adopting this technology very fast. The traditional methods of guava propagation are tedious, slow and produce less number of propagules. Recently grafting is getting popularity for propagation of guava. There is a tremendous scope for bringing substantial additional area under guava crop in Bundelkhand condition. To cope up the increasing demand of its quality planting material, an experiment was conducted to find out appropriate time for grafting of guava under semi-arid condition of Jhansi

MATERIALS AND METHODS

The experiment was conducted at Rani Lakhsmi Bai Central Agricultural University, Jhansi, during 2019-20. In a Factorial Randomized Block Design with 16 treatment combinations: Factor A comprising four different time of grafting; T_1: 1st fortnight of January, T_2: 2nd fortnight of January, T_3: 1st fortnight of February, T_4: 2nd fortnight of February, and Factor B consisted of four different varieties; S_1: Allahabad Safeda, S_2: L-49, S_3: Lalit, S_4: Shweta. For grafting operation, uniform and healthy guava seedlings of 10-12 month-old were selected as rootstock. The scion material was collected from the identified guava cultivar, *viz.* Allahabad Safeda, L-49, Lalit and Shweta. Immediately after grafting, grafts were covered with polyethylene caps, which was removed soon after sprouting and bud flushes of growth in scion.

Proper moisture was maintained and continuous weeding of polybags were performed. The sprouts on rootstocks were removed, regularly. After three months of grafting operation, the polyethylene strip tied around stock-scion junction was removed. The observation on graft takes, days required for bud sprouting, bud sprouting, final survival of grafts and different growth parameters of graftage, *i.e.* number of leaves, leaf area, number of shoots, length of scion, scion diameter, rootstock diameter, root density and stionic ratio were recorded. The quantitative data were analysed in a two-way ANOVA to determine differences in time of

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grafting and source of scion on grafting through WASP 2.0 (Web Based Agricultural Statistics Software Package, ICAR-CCARI, India). Critical difference for examining treatment means for their significance was calculated at 5% level of significance.

RESULTS AND DISCUSSION

Grafting time had significant effect on most of grafting related and growth parameters of guava saplings (Table 1 and Table 2). Highest value of graft take was obtained from 1st fortnight of February (96.9%), which was found at par with 2nd fortnight of January (93.3%), whereas lowest value of graft take was observed in 1st fortnight of January (83.8%). The grafting operation performed during 2nd fortnight of February (52.2 days) took minimum time, whereas 2nd fortnight of January (65.4 days) took maximum duration for bud sprouting. The maximum bud sprouting was noted from the grafting operation performed during 1st fortnight of February (91.1%), whereas minimum value of bud sprouting reported from 1st fort night of January (77.8%).

Maximum final survival was observed from 1st fortnight of February (90.1%), whereas minimum final survival was found in 2nd fortnight of February (59.8%). The congenial weather condition like optimum temperature and relative humidity helps in fast establishment of vascular tissue connections of rootstock and scion. Therefore, outdoor grafting operations should perform at that time of year when favourable temperature and relative humidity are prevailing, and the vascular cambium is in an active state. Similar effect of time on grafting success and other parameters were also observed in guava by Syamal *et al.*, 2012, Beer *et at.*, 2013, Rani *et al.*, 2015, and Gotur *et al.*, 2017.

Effect of scion source on most of grafting related parameters and growth parameters of guava saplings were found to be significant (Table 1). Maximum graft take was obtained from scion of L-49 (96.8%) which was found at par with Allahabad Safeda (95.9%), whereas minimum graft take was noted from scion of Shweta (80.9%). Among four different scion sources used for grafting operation, scion of Allahabad Safeda took minimum 55.3 days, whereas the scion of L-49 required maximum 61.6 days duration for bud sprouting.

Highest bud sprouting was observed from scion of of L-49 (91.5%) which was found at par with Allahabad Safeda (91.3%), whereas lowest bud sprouting was found from scion of Shweta (72.9%). The scion of L-49 expressed maximum (88.9%) final survival which was found at par with Allahabad Safeda (85.7%), whereas minimum final survival was observed from scion of

Table 1. Effect of time of grafting and source of scion on different grafting and growth-related parameters

Treatment	Graft take (%)	Days required for bud sprouting	Bud sprouting (%)	Final Survival	Number of leaves	Leaf area (cm^2)	Number of shoots	Length of scion (cm)	Scion diameter (cm)	Rootstock diameter (cm)
Time of grafting										
T_1 : (1st fort night of January)	83.8 (66.2)	57.2	77.8 (61.9)	75.9 (60.6)	21.0	55.0	3.2	23.1	0.68	0.73
T_2 : (2nd fort night of January)	93.3(77.8)	65.4	84.7 (67.0)	80.8 (64.0)	17.9	58.8	2.9	21.6	0.58	0.67
T_3 : (1st fort night of February)	96.9(79.8)	57.7	91.1 (72.6)	90.1 (71.7)	17.2	59.8	2.7	27.5	0.59	0.66
T_4 : (2nd fort night of February)	88.5(70.2)	52.2	82.7 (65.4)	73.2 (59.8)	18.3	48.8	2.5	18.2	0.56	0.60
CD at 5%	83.8 (66.2)	57.2	77.8 (61.9)	75.9 (60.6)	1.84	6.71	-	2.50	0.05	0.05
Source of Scion										
S_1 : Allahabad Safeda	95.9(78.3)	55.3	91.2 (72.7)	85.7 (67.8)	18.8	58.5	3.1	25.8	0.65	0.74
S_2 : L-49	96.8(80.0)	61.6	91.5 (73.0)	88.9 (70.3)	16.5	57.4	3.2	21.4	0.66	0.72
S_3 : Lalit	91.0(72.5)	57.0	78.5 (62.4)	75.9 (60.6)	19.7	58.3	2.4	23.5	0.58	0.60
S_4 : Shweta	80.9(64.1)	58.8	72.9 (58.8)	69.4 (57.3)	19.4	48.2	2.5	19.7	0.52	0.59
CD at 5%	(6.84)	(2.25)	(5.11)	(4.17)	1.84	6.71	0.58	2.50	0.05	0.05

*Figures in parenthes is are transform values

Table 2. Interaction effect of time of grafting and source of scion on different grafting and growth-related parameters

Treatment	Graft take (%)	Days required for bud sprouting	Bud sprouting (%)	Final survival	Number of leaves	Leaf area (cm^2)	Length of scion (cm)	Number of shoots	Length of scion (cm)	Scion diameter (cm)	Rootstock diameter (cm)
T_1S_1 (1^{st} fortnight of Jan+AS)	91.1(75.7)	62.0	86.7(68.6)	84.4(66.9)	21.3	54.0	23.7	3.7	23.7	0.74	0.80
T_1S_2 (1^{st} fortnight of Jan+L-49)	93.3(77.9)	53.3	91.4(72.9)	88.8(70.7)	19.7	52.1	21.0	4.0	21.0	0.79	0.83
T_1S_3 (1^{st} fortnight of Jan+Lalit)	75.6(61.5)	54.0	73.3(59.4)	71.1(58.0)	20.7	69.2	26.8	2.7	26.8	0.65	0.67
T_1S_4 (1^{st} fortnight of Jan+Shweta)	57.8(49.5)	59.0	53.3(46.9)	53.3(46.9)	22.3	44.8	21.0	2.3	21.0	0.54	0.60
T_2S_1 (2^{nd} fortnight of Jan+AS)	84.4(67.3)	64.0	84.4(67.3)	82.2(65.8)	17.0	61.1	30.0	3.7	30.0	0.68	0.80
T_2S_2 (2^{nd} fortnight of Jan+L-49)	100.0(90.0)	65.0	97.8(85.0)	95.6(80.0)	14.7	60.7	19.5	3.3	19.5	0.60	0.74
T_2S_3 (2^{nd} fortnight of Jan+Lalit)	97.8(85.0)	63.0	71.1(57.6)	66.7(55.4)	19.3	62.6	19.1	2.3	19.1	0.58	0.60
T_2S_4 (2^{nd} fortnight of Jan+Shweta)	86.7(69.0)	70.0	71.1(57.6)	66.6(55.3)	20.7	50.8	17.7	2.3	17.7	0.46	0.54
T_3S_1 (1^{st} fortnight of Feb+AS)	97.8(85.0)	51.0	93.3(75.0)	93.3(75.0)	20.0	70.3	32.1	3.7	32.1	0.60	0.76
T_3S_2 (1^{st} fortnight of Feb+L-49)	95.6(82.9)	59.3	93.3(75.0)	93.5(75.0)	14.7	69.2	26.9	3.0	26.9	0.63	0.66
T_3S_3 (1^{st} fortnight of Feb+Lalit)	95.6(82.9)	64.3	88.9(70.7)	88.9(70.7)	18.0	49.2	26.4	2.3	26.4	0.55	0.56
T_3S_4 (1^{st} fortnight of Feb+Shweta)	88.9(71.2)	56.0	84.4(66.9)	82.2(65.2)	16.0	50.4	24.3	2.7	24.3	0.57	0.64
T_4S_1 (2^{nd} fortnight of Feb+AS)	97.8(85.0)	44.0	95.6(80.0)	80.0(63.4)	16.7	48.4	17.2	2.3	17.2	0.56	0.61
T_4S_2 (2^{nd} fortnight of Feb+L-49)	82.2(65.1)	68.0	68.9(56.1)	66.7(54.8)	17.0	47.6	18.3	2.7	18.3	0.60	0.64
T_4S_3 (2^{nd} fortnight of Feb+Lalit)	80.0(63.6)	46.6	77.8(61.9)	73.3(59.0)	20.7	52.4	21.8	2.2	21.8	0.55	0.58
T_4S_4 (2^{nd} fortnight of Feb+Shweta)	84.4(66.9)	50.0	80.0(63.6)	77.8(61.9)	18.7	46.6	15.7	2.7	15.7	0.53	0.57
CD at 5%	(13.60)	4.49	(10.16)	(8.8)	-	13.42	5.00	-	5.00	0.09	0.10

*Figures in parenthes is are transform values

Shweta (69.4%). In fruit crops, different clones within a species can almost always be grafted without difficulty and produce satisfactory trees. In this study all the four different scion were grafted on the same seedling rootstock of same guava species. However, variation in success of grafting among different scion of same species can be observed. It might due to the genetic make-up of particular clone within a species may be having the more of live parenchymatous cells, less of vessels and higher meristematic activity at the bud level, which turn helps in better sap flow and good callus (Prasanth *et al.* 2007). Similar effect of source of scion on grafting success was reported by Syamal *et al.,* 2012, Visen *et al.,* 2010 and Kholia *et al.,* 2017(a) in guava, and Nowrozy, (2017) in pomegranate.

Interaction effect of grafting time and source of scion on most of the parameters was found to be significant (Table 2). Among all the treatment combinations cent percent graft take was observed from 2nd fortnight of January + L-49 (T_2S_2) at par with other treatment combinations T_2S_3, T_3S_1, T_4S_1, T_3S_2 and T_3S_3, whereas the lowest graft take value (57.8%) was found in 1st fortnight of January + Shweta (T_1S_4). In respect to days required for bud sprouting minimum value was noted from 2nd fortnight of February + Allahabad Safeda (44 days) and found at par with 2nd fortnight of February + Lalit (46 days), whereas maximum value was obtained from 2nd fortnight of February + L-49 (68 days). Highest bud sprouting recorded from treatment combination 2nd fortnight of January + L-49 (97.8%) found at par with 2nd fortnight of February + Allahabad Safeda (95.6%), whereas lowest bud sprouting noted in 1st fortnight of January + Shweta (53.3%).

Among all the treatment combinations maximum final survival of 95.6% obtained from 2nd fortnight of January + L-49 (T_2S_2) at par with T_3S_1 and T_3S_2, whereas minimum final survival observed from 1st fortnight of January + Shweta (53.3%). The desirable stonic ratio nearer to one was obtained from the treatment combinations 1st fortnight of January + Lalit (T_1S_3), 2nd fortnight of January + Lalit (T_2S_3) and 1st fortnight of February + Lalit (T_3S_3). The final survival of graft is depending of interaction of time of grafting and source of scion. Similar effect of time of grafting and source of scion by Syamal *et al.,* 2012, Visen *et al.* 2010 and Kholia *et al.,* 2017b in guava.

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Standardization of protocol for genomic DNA extraction and microsatellite marker (SSR, ISSR) analysis in spine gourd *(Momordica dioica)*

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ABSTRACT

The study evaluated reliable, easy and an efficient protocol for DNA extraction from young leaves of spine gourd which yielded highly pure with no visible discoloration concentrated genomic DNA ranged from 1202.68 to 3786.92 µg/500 mg of tissue with ratio (A_{260}/A_{280}) of absorbance ranging from 1.34 to 1.95. This method involved modification in original cetyl trimethyl ammonium bromide extraction without liquid nitrogen and by adding high level of β-mercaptoethanol, extracting twofold with chloroform: isoamyl alcohol (24: 1, v/v) and extending the centrifugation time which successfully removes polyphenols, chlorophyll pigments, polysaccharides and dyes. The DNA extracted by this method produced clearly scorable and reproducible definitive PCR fragments authentic exhibiting its compatibility and manifesting its affinity for SSR and ISSR markers. Therefore this method is recommended as an efficient protocol for genomic DNA extraction and microsatellite marker-based genetic analysis in spine gourd for high outp ut sample preparation for diverse PCR-based downstream applications.

Key Words: DNA extraction, Inter simple sequence repeat (ISSR), PCR amplification, Simple sequence repeat (SSR)

Spine gourd (*Momordica dioica* Roxb.) is a perennial climber of family Cucurbitaceae. The family includes about 118 genera and 825 species (Saroj and Choudhary, 2020). The inter-simple sequence repeats (ISSRs), have revolutionized various plant breeding approaches and offers various advantages over conventional phenotype-based alternatives (Jayanthi *et al.*, 2013). These markers have made a rapid impact in genetic relationship and marker-trait association studies of many cucurbitaceous plants (Mammadov *et al.*, 2012) which detects genetic variation at DNA level by using a single primer of arbitrary nucleotide sequence, besides it is ubiquitous and reliable due to their steadiness and is independent from environmental effects and developmental stages of plants (Primrose *et al.*, 2010). Such markers may have also direct applicability in marker-trait association studies and evaluation of linked marker in spine gourd using MADS-box genes (Mohanty and Joshi, 2018). Highly pure and intact DNA is required for any molecular studies; extraction of intact and highly pure genomic DNA from plant like spine gourd is challenging as it contains excessive level of secondary metabolites and other phyto-constituents which could co-participate and bind irreversibly with genetic material which leads oxidation and degradation of DNA which make it impure, unstable and unsuitable for further marker analysis (Sahu *et al.*, 2012). Thus, efforts were made to find standardized efficient protocol for genomic DNA extraction and microsatellite marker (SSR, ISSR) analysis in spine gourd.

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MATERIALS AND METHODS

Healthy young leaves of spine gourd landraces were collected from the experimental farm, Ambikapur,

India, located at latitude of 20°8'N, longitude of 83°15'E and altitude of 592.62 m MSL (mean sea-level). Laboratory work was performed at Plant Molecular Biology and Biotechnology Laboratory, section of Genetics and Plant Breeding, RMD CARS, Ambikapur, India. Cetyl trimethyl ammonium bromide extraction buffer; 5 g CTAB, 20.35 g NaCl were dissolved in 200 ml distilled water. Then 25 ml 1 M tris HCl and 10 ml 0.5 EDTA was added and it was vigorously agitated using magnetic stirrer. Final volume was made up to 250 ml and stored at ambient temperature. The 1 M tris HCl; 121.1 g of tris base was dissolved in 800 ml distilled water through magnetic stirrer and pH was adjusted up to 8.00 by adding up concentrated HCl, let it cool prior to making the final volume to 1000 ml.

The 0.5 M EDTA; dissolved 146.125 g of ethylene diamine tetraacetic acid $C_{10}H_{16}N_2O_8$, M.W. 292.25 in 800 ml distilled water by stirring it continuously through magnetic stirrer and pH was adjusted up to 8.00 by adding either putting NaOH / HCL and was cooled at ambient temperature and then adjusted to the final volume of 1000 ml. Chloroform: Isoamyl Alcohol (CIA) was taken in ratio of 24:1. The 50X TAE Buffer (for 150 ml, required tris base- 36.3g , 0.5 M EDTA - 15 ml, glacial acetic acid- 8.565 ml, and distilled water was added to made the final volume to 150 ml), 1X TAE (for 1 L tank buffer, add 20 ml 50X TAE to 980 ml of distilled water) and washing buffer (70% ethanol) is also required for sample preparation.

Plant genomic DNA was extracted from fresh young leaves of spine gourd following the previously reported CTAB DNA extraction method with some required modification which yielded convincing results in terms of quality and quantity both. Prior to start, 20 µl β-merceptoethanol was added in per 20 ml CTAB extraction buffer. Then 500 mg plant leaves were sterilized with 10% ethanol then it was grinded in 400 µl 2X, CTAB DNA extraction buffer with help of mortar and pestle. The grinded homogenised leaves and CTAB mixture was transferred in 2 ml eppendorf tube and then more 400 µl 2X, CTAB extraction buffer was added to it. Those tubes were put in water bath at 65°C for 15-20 min.

After that tubes were allowed to cool briefly then 700 µl Chloroform: Isoamyl Alcohol (CIA-24:1) was added and blended to it vigorously both by shaking it through hands intermittently and through vortex and later kept at room temperature for 15 min. Then it was centrifuged at 13,000 rpm for 5 min and the supernatant portion was collected in fresh 1.5 ml eppendorf tube and then again 700 µl CA:I was added to it and the process of centrifugation was repeated and supernatant was again transferred in fresh tubes. 900 µl chilled absolute ethanol was added on it and mixed gently.

Then the tubes were kept at -20°C for 2 hours. Further it was again centrifuged at 10,000 rpm for 20 min, the unsinkable was removed and the pellets were washed with 70% ethanol using short spin for 3 min at 10,000 rpm and then decanted the ethanol). After letting the DNA pellets to be air dried, it was dissolved in 50 µl TAE buffer. Further the quality of extracted spine gourd plant genomic DNA was measured by using 2% EtBr stained 1% agarose gel electrophoresis which was visualised under gel documentation system E-BOX CX5.TS (20 M) of Vilber Company and quantity of DNA was measured through spectrophotometer (UV-VIS Spectrophotometer, F7100, Hitachi).

The PCR amplification of spine gourd plant DNA was carried out in 22 µl PCR reaction mixture, composition of PCR material for one reaction included Molecular biology grade H2O (13.5 µL), PCR buffer (2.5 µL), dNTPs mix (1.5 µL), Primer (2 µL), DNA template (2 µL) and Taq polymerase (0.5 µL), Amplification was performed in dome shaped PCR tubes in Applied Biosystems 2720 thermal cycler. DNA was amplified using SSR and ISSR primer pair MdSSR 4 (forward sequence: 5'GTTTGAAAACGATGTGGTG3' and reverse sequence: 5'TCGCTCATAATGTT GTTAATG 3') and using UBC 808 (ISSR sequence: 5' AGAGAGAGAGAGAGAGC 3') at 52ºC and 50ºC annealing temperature respectively.

RESULTS AND DISCUSSION

The extracted spine gourd plant genomic DNA quality and quantity was assayed by gel electrophoresis and intense bands with no smear and degradation were observed on 2.5% EtBr stained 1% agarose gel, besides DNA quantity was recorded 1202.68 to 3786.92 µg / 500 mg which was similar / higher than acceptable range, indicates that DNA extracted with this protocol was pure and concentrated and it may be useful for PCR amplification for various downstream applications (Aboul-Maaty and Oraby, 2019). As spine gourd is a excellent source of secondary metabolites which imparts nutritional and medicinal values to it but also obstruct effective DNA isolation procedure and quality or purification of the isolated DNA as these constituents generally get accumulated and inhibits the enzymes activity which are commonly used in molecular biology such as polymerases, ligases and restriction endo-nucleases.

Contamination of polyphenol makes DNA defiant to restriction enzymes and interacts irretrievably with nucleic acids and proteins because polyphenols are powerful oxidizing agents which reduces purity and yield by binding covalently with isolated DNA and are discharged from vacuoles to react quickly with cytoplasmic enzymes during homogenization which

makes it impractical for several research applications such problem could be avoided using the present method of genomic DNA extraction especially in spine gourd. DNA extraction was standardized by changing a few of the measures in the actual CTAB DNA extraction protocol. The protocol is a reliable, easy, safe and worthwhile for DNA extraction in spine gourd, that imparts high quality genomic DNA amenable to SSR and ISSR markers and conquer the obstacle of co-precipitation of contaminating agents.

The main changes included in the protocol were cause of increased level of β-mercaptoethanol which prosperously eliminates the polyphenols (Ishfaq and Qadir, 2020), incubating at 60°C in water bath for only 15-20 minutes, use of CTAB instead of SDS which solubilises internal organelles of lipid membranes, denatures proteins and plant cell extracting two times with the chloroform : isoamyl alcohol (24:1, v/v) and extending the centrifugation time for 5 min which ensures removal of chlorophyll pigments and dyes. The DNA isolated from this method yielded strong, highly pure, non sticky white pellets with no visible discoloration, no visible RNA contamination, and gives definitive PCR fragments exhibiting its compatibility for SSR and ISSR markers. Hence consequently this method is suggested as an efficient protocol for genomic DNA extraction and microsatellite marker-based genetic analysis in spine gourd for high-output sample preparation in less equipped laboratories.

CONCLUSION

Quality and quantity of plant genomic DNA extracted were good and reproducible and was amplifiable using SSR and ISSR markers; therefore it is proved to be the most efficient protocol for DNA extraction and for PCR amplification using SSR and ISSR markers.

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Effect of PSB and vermicompost on yield and quality of garlic *(Allium sativum)*

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ABSTRACT

An experiment was conducted at R B S College, Bichpuri, Agra, during winter season of 2019-21 to find out the effect of phosphorus-solubilizing bacteria and vermicompost on yield and quality of garlic. The experiment was laid out in Randomized Block Design having three replications and seven treatments. The treatments were T_1 (control), T_2 (50% RDF + PSB), T_3 (50% RDF + vermicompost), T_4 (50% RDF + vermicompost + PSB), T_5 (80% RDF + PSB), T_6 (80% RDF + vermicompost) and T_7 (80% RDF + vermicompost + PSB). The application of 80% RDF + vermicompost + PSB) (T_7) recorded significantly maximum plant height (72.4 cm), green leaves/ plant, leaf length (60.9 cm), leaf width (1.69 cm), Fresh weight of top (15.60 g), polar diameter of bulbs (5.28 cm), equatorial diameter of bulbs (4.86 cm), neck thickness of bulbs (9.47 mm), highest longest clove (3.62 cm), total bulb yield (155.5 q/ha)dry weight of bulb (19.01 g) and leaves (1.98 g). While, all parameters were recorded minimum in the control.

Key Words: Vermicompost, Growth, Yield, Quality, Bulbs, Phosphate-solubilizing bacteria

Garlic (*Allium sativum* L.) is most widely cultivated crop throughout India mainly in Gujarat, Orissa, Madhya Pradesh, Rajasthan, Uttar Pradesh and Maharashtra. Phosphate-solubilizing bacteria (PSB) are not only able to solubilize insoluble forms of inorganic phosphorus but are also capable to mineralize organic forms of phosphorus, improving the availability of native soil phosphorus. Biofertilizers offer an economically-viable and ecologically sound route for augmenting nutrient supplies and can play a key role in bridging the gap between nutrient removal by crops and additions through fertilizers. It is very essential to develop sustainable and compatible agricultural practices through organic resources for different crops based on scientific facts. Keeping in view an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at RBS College Bichpuri, Agra, during *rabi* season of 2019-21. The experimental area is situated at 27.20 N latitude 78.50 East longitudes at height of 168 m above the mean sea-level. The climate of experimental site is sub tropical with large variation between summer and winter temperature. During summer, temperature ranges from 30°C to 46°C or even more during May and June, whereas in winter, it ranges from 1°C to 22°C. The mean annual precipitation fluctuates around 670 mm (average of last decade) and most part (84%) of it received during July - September and about 16 per cent of rain in rest of the year which is too erratic in distribution and intensity. The soil of the experimental field was fertile well drained sandy loam with good water holding capacity. The pH of the experimental soil was 8.2. The soil had 168.0 kg/ha available potassium, 14.0 kg/ha available phosphorus, 147 kg/ha available nitrogen and 3.0g kg/ha organic carbon.

The experiment was laid out in Randomized Block Design having three replications and seven treatments. The treatments were; T_1 (control), T_2 (50% RDF + PSB), T_3 (50% RDF + vermicompost), T_4 (50% RDF + vermicompost + PSB), T_5 (80% RDF + PSB), T_6 (80% RDF + vermicompost) and T_7 (80% RDF + vermicompost + PSB). Uniform and healthy cloves were planted at the spacing of 15 cm × 10 cm. Recommended dose of RDF (120:80:60 kg NPK/ha) as

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per treatment were applied through DAP, urea and muriate of potash, respectively. Full amount of P_2O_5, K_2O and half of nitrogen along with vermicompost as per treatment was applied as a basal dressing before transplanting and rest of the nitrogen was applied after second irrigation through urea as top dressing.

Phosphorus-solubilizing bacteria (PSB) was applied by dip method. Slurry of phosphorus-solubilizing bacteria was prepared in plastic bucket and cloves of garlic were dipped in this solution for 25-30 minutes and then sown in field as per the layout. Observations on plant height, number of leaves / plant, leaf size, neck thickness of bulbs, bulb diameter, fresh weight of top, number of cloves / bulb, length of longest clove and bulb yield were recorded at peak stage. The data on various parameters were analysed statistically as suggested by Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

The data revealed that treatment T_7 (80% RDF + vermicompost + PSB) significantly influenced the vegetative growth parameters. The maximum plant height (62.4 cm), number of leaves / plant (9.32), leaf length (60.91 cm), leaf width (1.69 cm), and fresh weight of top (15.7 g), were found to be significantly higher in T_7 (80% RDF + vermicompost + PSB), followed by T_6 (80% RDF + vermicompost), while / these all growth parameters were recorded minimum in the control (T_1).

Nitrogen is one of the major key elements for the vegetative growth and increase in N supply accelerates the synthesis of chlorophyll and amino acids which enhanced the vegetative growth in terms of leaf length and number of leaves per plant. Phosphorus hastens leaf development and encourages greater growth of roots, while potassium improves the health and vigour of plant, enabling it to withstand adverse climatic conditions. The fact for increased growth parameters may be due to the improvement in growth related attributes because of certain growth promoting substances secreted by biofertilizers, better uptake of water, nutrients and their transportation. Similar results were also observed by Meena, *et al.* (2018) and Kumar *et al.* (2019).

The data revealed that treatment T_7 (80% RDF + vermicompost + PSB) significantly influenced yield and quality parameters of garlic (Table 1). The maximum polar diameter of bulb (3.45 cm), equatorial diameter of bulb (4.86 cm), neck thickness of bulb (9.47 mm), highest longest clove (3.62 cm), number of cloves / bulb (24.15), total bulb yield (155.5 q / ha), dry weight of bulb and leaves (19.01 g and 1.98 g) were found under the treatment T_7 (80% RDF + vermicompost + PSB), followed by T_6 (80% RDF + vermicompost). However, the minimum values were recorded under control (T_1) in above all parameters.

The possible reason for polar, equatorial diameter and neck thickness of bulb may be due to combined application of biofertilizers and organic fertilizer along with inorganic fertilizers which attributed to the fact that biofertilizers are known to synthesize the growth promoting substances besides increasing the availability of atmospheric soil phosphorus, which might have led to luxuriant bulb size. The same findings were also reported by Meena *et al.* (2019). The increase in bulb weight could be due to increased uptake of nutrients and build-up of sufficient photosynthates enabling the increase in size of bulbs, ultimately resulting in the increased average bulb weight. These results are in confirmation with the findings of Kumar *et al.* (2019). The possible reason for increases in yield is might be due to more number of bulbs per plot, bulb size and average weight of bulbs. Use of vermicompost and PSB not only makes the soil nitrogen and phosphorus available, to plants but also enhances the plant growth and bulb yield due to release of hormones,

Table 1. Effect of PSB and vermicompost on yield and quality parameters (mean of 2 year)

Treatment	Polar diameter of bulbs (cm)	Neck thickness (mm)	Number of cloves/ bulb	Length of longest clove (cm)	Dry weight of leaves(g)	Dry weight of bulb(g)	Total bulb yield (q/ha)
T_1 (control)	3.45	7.25	15.98	2.67	0.97	17.16	131.9
T_2 (50% RDF+PSB)	3.70	7.74	21.28	3.08	1.27	17.60	134.6
T_3 (50% RDF+vermicompost	3.75	8.17	21.72	3.22	1.33	17.64	143.4
T_4 50% RDF+vermicompost+PSB	4.27	8.65	22.38	3.25	1.65	17.94	149.0
T_5 80% RDF+PSB	4.24	8.39	21.81	3.25	1.41	17.83	147.0
T_6 80% RDF+vermicompost	4.81	9.07	22.96	3.28	1.72	18.23	153.3
T_7 80% RDF+vermicompost+PSB	5.28	9.47	24.15	3.62	1.98	19.01	155.5
(P=0.05)	0.46	0.80	1.09	0.138	0.32	0.76	2.10
SEm±	0.149	0.26	0.35	0.045	0.104	0.25	0.68

vitamins and nutrients. Similar findings were also reported by Thangasamy *et al.* (2010) and Kumar *et al.* (2019).

CONCLUSION

Thus, it may be concluded that application of 80% RDF + vermicompost + PSB) was found superior among all other treatments for increasing vegetative growth and quality yield of garlic.

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Effect of essential heavy metals on chlorophyll and carotenoid content in tuberose *(Polianthus tuberosa)*

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ABSTRACT

Three essential heavy metal containing chemicals, *viz*. $MnSO_4$, $CuSO_4$ and $ZnSO_4$ were used at three concentrations to study their influence on content of leaf pigments, *viz.*, chlorophylls and carotenoids in tuberose cv. 'Prajwal'. The experiment was conducted at College of Horticulture, Dr Y.S.R. Horticultural University, Anantharajupeta village, Kadapa district of Andhra Pradesh, following the polybag culture, in a Completely Randomized Design with factorial concept using three replications. Data recorded on the content of chlorophylls and carotenoids in the leaves of tuberose cv. 'Prajwal' were analyzed statistically using OPSTAT software and the least significant difference was used to differentiate the treatments. Statistical analysis of results indicated that application of $ZnSO_4$ @ 400 mg/kg soil recorded a significant improvement in contents of chlorophyll-a (0.047, 0.074 and 0.060) and chlorophyll-b (0.029, 0.059 and 0.044) mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis, whereas total chlorophylls content (0.058 mg/g fresh weight of leaves)was found significant only during 2018-19.Significantly highest total carotenoids content (1.77, 2.43 and 2.10 mg/g fresh weight of leaves) was recorded respectively during 2018-19, 2019-20.

Key Words: $MnSO_4$, $CuSO_4$, $ZnSO_4$, Chlorophyll-a, b, Carotenoids

Certain heavy metals are required in specific amounts and their deficiency or elevated concentration will result in deleterious effects on plant growth and development of the heavy metals, three essential metals, *viz.* Mn, Cu and Zn are required in trace amounts for better growth, development and metabolic activity of plants hence, have been selected in the present investigation to identify their toxic effects on metabolic activity of plants. Keeping all these in view, the experiment was conducted to find out the effect of graded levels of essential heavy metals (Mn, Cu, Zn) on content of chlorophylls and carotenoids in *Polianthus tuberosa cv*. 'Prajwal'.

MATERIALS AND METHODS

The study was carried out during *rabi*-2018 to *kharif*-2020 at College of Horticulture, Dr Y.S.R. Horticultural University, Anantharajupeta, Kadapa district of Andhra Pradesh, India. The experiment consisted of 10 treatments, *viz*., T_1 = RDF + $MnSO_4$ @ 1,000 mg/ kg soil, T_2 = RDF + $MnSO_4$ @ 2,000 mg/kg soil, T_3 = RDF + $MnSO_4$ @ 3,000 mg/kg soil, T_4 = RDF + $CuSO_4$ @ 100 mg/kg soil, T_5 = RDF + $CuSO_4$ @ 200 mg/kg soil, T_6 = RDF + $CuSO_4$ @ 300 mg/kg soil, T_7 = RDF + $ZnSO_4$ @ 200 mg/kg soil, T_8 = RDF + $ZnSO_4$ @ 400 mg/kg soil, T_9 = RDF + $ZnSO_4$ @ 600 mg/kg soil, T_{10} = control (No RDF and no heavy metals). Chlorophyll content in fresh leaves of each replication of treatment was determined. Leaf sample at the rate of 500 mg was taken into a 50 ml conical flask, added 10 ml of dimethyl sulphoxide (DMSO) and covered with an aluminum foil. Kept the samples at 70°C in hot air oven for 4 hours. Filtered the solution using Whatman filter paper number 42. One ml of the filtered pure solution was taken out and diluted to 5 ml with dimethyl sulphoxide. Samples were read at 645 and 663 nm in an UV-VIS spectrophotometer (Shimadzu UV-1800) using pure dimethyl sulphoxide as blank. Concentration of

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photosynthetic pigments were converted into mg per gram fresh weight of leaf. Chlorophyll-a, chlorophyll-b and total chlorophyll contents in the leaves were calculated by using the following formulae.

Chlorophyll a (mg/g) =

$$\frac{(12.7 * A663\ nm) - (2.69 * A645\ nm) * V * D}{W(g) * 1000}$$

Chlorophyll b (mg/g) =

$$\frac{(22.7 * A645\ nm) - (4.68 * A663\ nm) * V * D}{W(g) * 1000}$$

Total chlorophyll (mg/g) =

$$\frac{(20.2 * A645\ nm) - (8.02 * A663\ nm) * V * D}{W(g) * 1000}$$

where,

'A' is absorbance at specific wavelength, 'V' is the final volume of chlorophyll extract, 'D' is dilution factor and 'W' is fresh weight of leaf tissue.

Total carotenoids content in fresh leaves of each treatment was determined by the method explained by Wellburn (1994). Sample of 500 mg of leaf was taken in to a 50 ml conical flask and added 10 ml of dimethyl sulphoxide (DMSO) and covered the conical flask with aluminum foil. Kept the samples at 70°C in a hot air oven for 4 hours and then filtered the solution using Whatman filter paper number 42. One ml of above aliquot was taken out and diluted to 5 ml with DMSO and then the samples were read at 480 nm in a UV-VIS spectrophotometer (Shimadzu UV-1800) using pure DMSO as blank.

Total carotenoids (mg/g) =

$$\frac{1000 \times A480\ nm - 1.29Ca - 53.78Cb}{220}$$

where, Ca = Chlorophyll-a Cb = Chlorophyll-b

The data was analyzed using OPSTAT software and the treatments were differentiated by using the least significant difference.

RESULTS AND DISCUSSION

Significant variation was recorded among the graded levels of essential heavy metal concentrations with respect to the content of chlorophyll-a. Among the graded levels of essential heavy metal concentrations, application of $ZnSO_4$ @ 400 mg/kg soil recorded significantly highest content of chlorophyll-a (0.039, 0.059 and 0.049 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis), whereas the remaining all other treatments irrespective of the essential heavy metal and its concentrations were found at par with the application of ZnSO4 @ 200 mg/kg soil during 2018-19, except the untreated control.

However, application of $ZnSO_4$ @ 200 mg/kg soil was found at par with the application of $MnSO_4$ @ 2000 mg/kg soil and application of $CuSO_4$ @ 100 & 300 mg/kg soil during the 2nd year of study, *i.e.* 2019-20 and the pooled data analysis. Among the concentrations of $MnSO_4$, application of $MnSO_4$ @ 1000 & 3000 mg/kg soil recorded significantly lowest and non-significant differences between the concentrations with respect to the content of chlorophyll-a in comparison with the application of $MnSO_4$ @ 2000 mg kg-1 soil. Among all treatments, untreated control recorded significantly lowest content of chlorophyll-a (0.004, 0.006 and 0.005 mg g^{-1} fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis).

Among the intervals, significantly highest content of chlorophyll-a (0.027, 0.043 and 0.035 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 days after planting (DAP) interval, whereas significantly lowest content of chlorophyll-a (0.015, 0.017 and 0.016 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded during the initial 90 DAP interval.

Among interaction effects, significantly highest content of chlorophyll-a (0.047, 0.074 and 0.060 mg/g fresh weight of leaves) was recorded by application of $ZnSO_4$ @ 400 mg/kg soil at 360 DAP interval followed by application of $ZnSO_4$ @ 200 mg kg^{-1} at 270 DAP interval (0.039, 0.073 and 0.054 mg/g fresh weight of leaves) respectively during 2018-19, 2019-20 and the pooled data analysis, whereas significantly lowest content of chlorophyll-a (0.001, 0.002 and 0.001 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded in the untreated control plants during the initial 90 DAP interval. Somdutt and Bhambotta (1966) found positive relationship between Zn application and the content of chlorophylls in citrus. Significant increase noticed in the content of chlorophyll-a in tuberose cv. 'Prajwal' by the application of $ZnSO_4$ @ 400 mg/kg soil at 360 DAP interval might be obviously due to the soil application of graded levels of $ZnSO_4$ which acted as a constituent of chlorophyll structure and catalytic component of proteins, enzymes and as a co-factor for the normal development of pigment biosynthesis (Balashouri and Devi, 1995).

The present result in terms of increased chlorophyll content in the leaves of tuberose cv. 'Prajwal' was found in close agreement with the earlier findings of Muthumanikam *et al.* (1999) in gerbera, Balakrishnan *et al.* (2007) in African marigold, Janakiram *et al.* (2013) in chrysanthemum, Halder *et al.* (2007) in gladiolus and Kumar *et al.* (2009) in chrysanthemum.

The application of $ZnSO_4$ @ 400 mg/kg soil recorded significantly highest content of chlorophyll-b (0.025, 0.052 and 0.038 mg g^{-1} fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) followed by application of $ZnSO_4$ @ 200 mg/kg soil which was found at par with the application of $MnSO_4$ 3000 mg/kg soil and $CuSO_4$ @ 100 mg kg^{-1} soil respectively during 2018-19, 2019-20 and the pooled data analysis. The untreated control plants recorded significantly lowest content of chlorophyll-b (0.005, 0.008 and 0.006 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis).

Based on the analysis of results, it may be concluded that application of $ZnSO_4$ @ 400 mg/kg soil increased the content of chlorophyll-b in the leaves of tuberose cv. 'Prajwal' which might be attributed to increased synthesis of chlorophyll content in the leaves as zinc has been considered as a constituent of chlorophyll pigment. Hebbar *et al.* (2004) noticed an accelerated synthesis of chlorophyll pigment in the leaves of tomato without altering the composition of chlorophyll-a and -b by application of increased quantities of zinc sulphate in the soil.

There was significantly highest content of chlorophyll-b (0.017, 0.037 and 0.026 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 DAP interval, whereas significantly lowest content of chlorophyll-b (0.010, 0.020 and 0.016 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at the initial 90 DAP interval.

The chlorophyll-b was recorded during both the years as well as in the pooled data analysis. However, non-significant differences in the content of chlorophyll-b were noticed in between 270 and 360 DAP intervals during 2018-19 and 90 and 180 DAP intervals during 2019-20 as well as in the pooled data analysis. Among the combination treatments, significantly highest content of chlorophyll-b (0.029, 0.059 and 0.044 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded by application of $ZnSO_4$ @ 400 mg/kg soil at 360 DAP interval followed by application of $ZnSO_4$ @ 200 mg/kg soil at 270 DAP interval (0.026, 0.055 and 0.040 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis), whereas significantly lowest content of chlorophyll-b (0.001, 0.003 and 0.002 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded in the untreated control plants at the initial 90 DAP interval.

Hebbar *et al.* (2004) reported that application of zinc on the plant might have accelerated the synthesis of chlorophyll content in the leaves without altering the composition of chlorophyll -a and -b, as zinc was considered as the constituent of chlorophyll molecule. The phenomenon of increased content of chlorophyll-b with increased availability of micronutrients especially supply of Zn and Mn in the present study was found in accordance with the earlier reports of several research workers *viz.*, Meenakshi and Vadivel (2003) in bitter gourd, Virghine-Tenzia (2003) and Balasubramaniam (2008) in tomato and Thirugnanavel *et al.* (2018) in musa.

The application of $ZnSO_4$ @ 400 mg/kg soil recorded significantly highest total chlorophyll content (0.049, 0.113 and 0.053 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis). Among the zinc sulphate concentrations, application of $ZnSO_4$ @ 600 mg/kg soil recorded significantly lowest total chlorophyll content in tuberose cv. 'Prajwal', whereas application of $ZnSO_4$ @ 200 mg/kg soil recorded moderate content of total chlorophyll during both the years of study as well as in the pooled data analysis.

The untreated control plants recorded significantly lowest total chlorophyll content (0.005, 0.012 and 0.009 mg/g fresh weight of leaves) respectively during 2018-19, 2019-20 and the pooled data analysis. Among the intervals, significantly highest total chlorophyll content (0.037 and 0.039 mg/g fresh weight of leaves respectively during 2018-19 and the pooled data analysis) was recorded at 360 DAP interval, whereas significantly lowest total chlorophyll content (0.024 and 0.021 mg/g fresh weight of leaves respectively during 2018-19 and the pooled data analysis) was recorded during the initial 90 DAP interval. A gradual increase was recorded in the total chlorophyll content of tuberose cv. 'Prajwal' during both the years of study as well as in the pooled data analysis.

The total chlorophyll content of leaves increased with an increase in the age of the plant. Among the combination treatments, significantly highest total chlorophyll content (0.058 mg/g fresh weight of leaves) was recorded by application of $ZnSO_4$ @ 400 mg/kg soil at 360 DAP interval followed by application of $ZnSO_4$ @ 200 mg/kg soil at 270 DAP interval (0.051 mg/g fresh weight of leaves), whereas significantly lowest total chlorophyll content (0.001 mg/g fresh weight of leaves) was recorded in the untreated control plants at 90 DAP interval during 2018-19.

Based on the analysis of results, it may be concluded that application of $ZnSO_4$ @ 400 mg/kg soil recorded an increase in the total chlorophyll content of leaves in tuberose cv. 'Prajwal' which may be due to involvement of zinc in the formation of chlorophyll, where zinc was

considered as a constituent of chlorophyll pigment. Balashouri and Devi (1995) reported that application of zinc sulphate acted as a structural and catalytic component of protein synthesis, enzyme's activity and as a co-factor in the biosynthesis of chlorophyll pigments.

The essential heavy metal concentrations, application of $ZnSO_4$ @ 400 mg/kg soil recorded significantly highest total carotenoids content (1.75, 2.03 and 1.90 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) followed by application of $ZnSO_4$ @ 200 mg/kg soil. Among the concentrations of $ZnSO_4$, application of $ZnSO_4$ @ 600 mg/kg soil recorded significantly lowest total carotenoids content during both the years of study as well as in the pooled data analysis. The untreated control plant recorded significantly lowest total carotenoids content (0.21, 0.64 and 0.42 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis). Among the intervals of observation, significantly highest total carotenoids content (1.21, 1.75 and 1.48 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 DAP interval, whereas significantly lowest total carotenoids content (0.68, 0.86 and 0.78 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded during the initial 90 DAP interval.

A gradual and significant increase in the total carotenoids content of tuberose cv. 'Prajwal' was noticed at each successive interval of observation during both the years of study as well as in the pooled data analysis. However, non-significant differences were observed in the total carotenoids content of tuberose leaves recorded on 90 and 180 DAP intervals during 2018-19. Among the combination treatments, significantly highest total carotenoids content (1.77, 2.43 and 2.10 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded by application of $ZnSO_4$ @ 400 mg/kg soil at 360 DAP interval followed by application of $ZnSO_4$ @ 200 mg/kg soil at 270 DAP interval (1.76, 2.24 and 1.99 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis), whereas significantly lowest total carotenoids content (0.15, 0.40 and 0.28 mg/g fresh weight of leaves respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded in the untreated control plants at 90 DAP interval.

Thus, it may be concluded that soil application of zinc sulphate enhanced the content of carotenoids in the plant tissue which has reduced the damage caused by reactive oxygen species, which in turn increased the chlorophyll content of such plants. Increased concentration of photosynthetic pigment in the plant tissue subject to supply of zinc under heavy metal stress might have enhanced the activity of Rubisco and PEP carboxylase enzymes under stress.

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Evaluation of onion *(Allium cepa)* varieties for their suitability in tribal area of Dungarpur, Rajasthan

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ABSTRACT

An experiment was conducted to evaluate onion varieties for the suitability in Dungarpur, Rajasthan, during 2017-18 and 2018-19. Six high-yielding varieties were tested with five replications in comparison to local variety. Different treatments included onion variety Agrifound Light Red, NHRDF Red, NHRDF Red-2 NHRDF Red-3, NHRDF Red-4 and local variety Udaipur 103. The NHRDF Red-3 produced maximum height of plant (56.46 cm) and number of leaves/plant (17.30). While, NHRDF Red-4 was at par in height of plant (54.24 cm) and number of leaves/plant (17.20). The NHRDF Red recorded minimum (1.04 cm) neck thickness which was at par with Agrifound Light Red (1.11 cm), Udaipur 103 and NHRDF Red-4 (1.16 cm). However, NHRDF Red-3 recorded maximum neck thickness (1.30 cm). The maximum average fresh weight of bulb (98.48 gm) and cured weight of bulb (95.81 gm) were recorded with variety NHRDF Red-3, while NHRDF Red-4 was at par for fresh bulb (92.70 g) and for cured weight of bulbs (89.72 g). The maximum polar diameter of bulb (47.05 mm) and equatorial diameter of bulbs (48.76 mm) were recorded variety NHRDF Red-3, while NHRDF Red-4 was at par for polar diameter of bulbs (44.80 mm) and for equatorial diameter of bulbs (46.56 mm). The NHRDF Red-4 and Agrifound Light Red (153) required minimum days for maturity which was at par with local variety Udaipur 103 (162), while NHRDF Red-2 and NHRDF Red-3 (160) recorded maximum days.

Key Words: Yield, Suitability, Variety, Tribal area, Neck thickness, Polar diameter

India is the second largest producer of onion (*Allium cepa* L. var. cepa) in the world. Onion can be grown under a wide range of climatic condition but succeeds best in mild season without extremes of heat and cold. Successful onion production depends on selection of varieties that are adapted to different climatic conditions. Mahala *et al.*, (2019) revealed that transplanting of onion in 15 × 10 cm geometry recorded maximum plant height (30.87 cm) which was statistically at par with 10 cm × 10 cm crop geometry (28.93) but significantly different from 10 cm × 7.5 cm (24.87 cm). However, no systematic study has been conducted to assess the suitability of onion cultivation in Dungarpur district of Rajasthan. Therefore, an experiment was conducted to study the response of improved varieties of *rabi* onion for their suitability for cultivation in Dungarpur district of Rajasthan.

MATERIALS AND METHODS

The study was carried out at Krishi Vigyan Kendra, Faloj farm, Dungarpur, during *rabi* season 2017-18 and 2018-19. The experiment consisted of six varieties namely Agrifound Light Red, NHRDF Red, NHRDF Red-2, NHRDF Red 3, NHRDF Red-4 and local variety (Udaipur 103) was laid out in randomized block design with five replications. The raised beds 1m wide and 3m long were prepared and elevated up to 20 cm from ground levels. Treated seeds with *Bavistin* @ 1g/kg of seeds of different varieties were sown on the raise beds in rows 5 cm apart. After sowing seeds were covered with a thin layer of sieved farmyard manure. Seedlings treated with Bavistin were transplanted in the plots at a spacing of 15 cm × 10 cm. Transplanting was done in the afternoon hours immediately followed by irrigation for proper establishment of seedlings. Gap filling was carried out after a week of transplanting and light irrigation applied just after gap filling of seedlings.

The experimental field was kept weed free throughout the crop growth period. Timely manuring and fertilization were carried out by applying recommended doses of nitrogen (120 kg/ha),

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phosphorus (60 kg / ha), potassium (60kg / ha) and sulphur (25 kg / ha) were applied in each plot. The first light irrigation was given just after sowing and thereafter as and when needed depending upon moisture availability in the soil and was withheld before 20 days of harvest. The crop was harvested when 75 per cent tops start falling over but before the foliage is completely dry.

Ten plants were randomly selected in each entry to record observations on growth, yield, quality parameters, pests and disease incidence. Economics of onion was worked out based on the current market price of inputs and outputs. The observation on plant height, number of leaves per plant and leaf diameter was calculated at 90 DAT. At the time of harvesting, the parameters recorded were bolting, neck thickness of the bulb, polar diameter, equatorial diameter, fresh weight of bulb and bulb yield.

RESULTS AND DISCUSSION

The plant height was recorded at 90 DAT (days after transplanting), showed maximum plant height (56.46 cm) in NHRDF Red-3 which was at par with NHRDF Red-4 (54.24 cm), Agrifound Light Red (52.08 cm), NHRDF Red-2 (45.14 cm), NHRDF Red (43.76 cm). Whereas minimum plant height was recorded by local variety Udaipur 103 (41.57 cm) respectively. Similarly at 90 DAT NHRDF Red-3 recorded maximum (17.30) number of leaves / plant which was at par with NHRDF Red-4 (17.20), Agrifound Light Red (16.88) NHRDF Red and NHRDF Red-2(16.74). Udaipur 103 recorded minimum (15.99) number of leaves / plant. These differences in plant height and number of leaves / plant are due to different varietal characters. Similar results were reported by Lawande *et al.*, (2011), Dwivedi *et al.*, (2012), Tripathy *et al.*, (2013), Kerure *et al.* (2016), Peerzade and Harish Babu (2017), Sahoo, *et al.*, (2020).

The maximum average fresh weight of bulb (98.48 gm) and cured weight of bulb (95.81 gm) were recorded with variety NHRDF Red-3, while NHRDF Red-4 at par for fresh bulb (92.70 gm) and for cured weight of bulb (89.72 gm), whereas local variety Udaipur 103 recorded minimum fresh weight of bulb (90.03 gm) and cured weight of bulb (71.12 gm). These differences in fresh weight of bulb and cured weight of bulb are due to different varietal characters of *rabi* onion. Similar results were reported by Hirave *et al.* (2015), Peerzade and Harish Babu (2017), Sahoo, *et al.*, (2020) and Dikshit, *et al.*, (2020).

NHRDF Red recorded minimum (1.04 cm) neck thickness which was at par with Agrifound Light Red (1.11 cm), Udaipur 103 and NHRDF Red-4 (1.16 cm). However, NHRDF Red-3 recorded maximum neck thickness (1.30 cm) which was at par with NHRDF

Table 1. Pooled analysis of economics of different *rabi* onion varieties

Variety	Total bulbs yield (q/ha)			Gross return (₹/ha)			Net return (₹/ha)			B:C ratio		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
Udaipur 103	190.4	199.1	194.75	133280	99600	116440	91530	57610	74570	2.19	2.37	2.28
AFLR	256.9	259.3	258.1	231210	129250	180230	187520	86270	136895	5.29	3.01	4.15
NHRDF Red	266.6	261.2	263.9	213280	130700	171990	167330	88210	127770	4.64	3.08	3.86
NHRDF Red-2	264.2	266	265.1	211360	132295	171828	164510	89960	127908	4.71	3.08	3.89
NHRDF Red-3	273.4	277.2	275.3	273400	138300	205850	227410	95150	161280	5.94	3.21	4.57
NHRDF Red-4	272.6	270.2	271.4	245348	135000	190174	200918	91050	145984	5.52	3.07	4.30

Red-2 (1.19 cm). The neck thickness of bulb correlated with diameter, number of leaves, thus increase in size exerts similar increase in neck thickness. These results are in close agreement with of Dewangan *et al.*, (2012), Hirave *et al.,* (2015), Sahoo, *et al.,* (2020) and Dikshit *et al.* (2020).

The NHRDF Red-3 recorded minimum (00%) bolting of bulb which was at par with Agrifound Light Red (0.04%), NHRDF Red-4 (0.06%), NHRDF Red (0.78%) and NHRDF Red-2(1.50%), whereas, maximum (6.38%) bolting of bulb was recorded in Udaipur 103. It may be due abruptly high temperature prevalence throughout the crop period and varietal character. These results are in conformity with the findings of Hirave *et al.,* (2015), Peerzade and Harish Babu (2017), Sahoo, *et al.* (2020) and Dikshit, *et al.* (2020).

The NHRDF Red-4 and Agrifound Light Red (153) required minimum days for maturity. While NHRDF Red-2 and NHRDF Red-3 (160) recorded maximum days. These differences in maturity period of bulb were observed due to different genetic constitution of onion varieties. Lawande *et al.,* (2011), Tripathy *et al.,* (2013), Kerure *et al.,* (2016), Peerzade and Harish Babu (2017), Sahoo, *et al.* (2020) and Dikshit *et al.* (2020) also reported influence of *rabi* onion varieties on days required for maturity.

The maximum polar diameter of bulb (47.05 mm) and equatorial diameter of bulb (48.76 mm) were recorded with variety NHRDF Red-3, while NHRDF Red-4 at par for polar diameter of bulb (44.80 mm) and for equatorial diameter of bulb (46.56 mm), whereas Udaipur 103 recorded minimum polar diameter of bulb (39.08 mm) and equatorial diameter of bulb (38.21 mm). Similar results were reported Dwivedi *et al.,* (2012), Lawande *et al.,* (2011), Tripathy *et al.,* (2013), Hirave *et al.,* (2015), Kerure *et al.,* (2016), Peerzade and Harish Babu (2017), Sahoo, *et al.,* (2020) and Dikshit *et al.* (2020).

The increase in yield could also be due to plant height, leaf number, chlorophyll content, bulb diameter, leaf diameter, equatorial diameter, pseudo stem length and fresh weight of bulb. Similar results were reported Ijoyah *et al.,* (2008), Sarada *et al.,* (2009), Dwivedi *et al.,* (2012), Lawande *et al.* (2011), Tripathy *et al.* (2013), Hirave *et al.* (2015), Kerure *et al.* (2016), Peerzade and Harish Babu (2017), Sahoo, *et al.,* (2020) and Dikshit *et al.,* (2020) under different climatic conditions with different varieties.

The results revealed that bulb yield (275.3 q/ha) was reported from onion variety NHRDF Red-3, followed by NHRDF Red-4 (271.4 q/ha), NHRDF Red-2 (265.1 q/ha), NHRDF Red (263.9 q/ha) and Agrifound Light Red (258.1 q/ha) and the lowest by local variety Udaipur 103 (194.7 q/ha) during 2017-18 and 2018-19 (Table 1). The variations in bulb yield of different varieties of onion also been reported from several places. Similar results were also obtained from the works of Lawande *et al.,* (2011), Tripathy *et al.,* (2013) Kerure *et al.,* (2016), Sahoo, *et al.,* (2020) and Dikshit, *et al.,* (2020).

The economic analysis of the data (Table) revealed that NHRDF Red 3 variety recorded higher gross returns (₹ 205850/ha), net returns (₹ 161280/ha) and B:C ratio of 2.28 compared to local variety Udaipur 103. A similar better economic return by cultivation of NHRDF Red 3 variety compared to other varieties was reported by Kerure *et al.* (2016), Sahoo, *et al.,* (2020) and Dikshit, *et al.,* (2020).

The NHRDF Red 3 variety was most preferred *rabi* onion compared to NHRDF Red-4, Agrifound Light Red, NHRDF Red-2, NHRDF Red and Udaipur 103. The farmers perceived and ranked NHRDF Red-3 was number one as this variety produced good size of bulbs, attractive shape, colour, better yield, keeping quality and market preference (Table 2). NHRDF Red-4 was ranked number two. While Udaipur 103 recorded lowest preference because farmers did not appreciate its size, shape, colour, skin, lower yield, storage quality and market preference along with its nature of susceptibility to purple blotch and proneness to damping off disease. However based on seed availability for current season crop production,

Table 2. Varietal performance and farmers' perception on various characters of *rabi* onion

Variety	Size	Shape	Colour	Yield	Keeping quality	Market preference	Availability of seeds	Total points	Ranking
Udaipur 103	4	3	4	4	3	4	3	25	VI
Agrifound Light Red	2	2	2	5	2	2	1	16	III
NHRDF Red	2	2	2	4	4	4	4	22	V
NHRDF Red-2	2	2	2	3	3	3	4	19	IV
NHRDF Red-3	1	1	1	1	1	1	1	7	I
NHRDF Red-4	1	1	1	2	2	1	2	10	II

Preference scale: 1-6 (1- highest preference, 6- lowest preferences)

Udaipur 103 ranked number one, compared to other six varieties. Similar evaluation of *rabi* onion varieties for productivity performance was reported by Baliyan, (2014), Dikshit *et al.*, (2020) and Sahoo *et al.*, (2020).

CONCLUSION

The results of different varieties tested for cultivation in *rabi* season revealed that NHRDF Red-3 can be adopted for cultivation in Dungarpur district of Rajasthan.

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Structural break analysis on specific horticultural crops in India

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ABSTRACT

The study attempts to investigate the presence of structural change in growth of area, production and productivity of selected horticultural crops in India from 1997-98 to 2018-19. The CGR and structural break analysis were employed to examine the growth rates and multiple break periods respectively. The CGR results show that area and production of selected horticultural crops in India grew more during post NHM period than pre NHM period, but there is not a significant growth in productivity of major crops. The structural break analysis shows that shift in growth has been reported after 2005 in selected crops implied that significant growth trend has been observed after NHM implementation. The overall performance in area, production and productivity is quite satisfactory during post-NHM period in major crops except in pepper and tapioca.

Key Words: Growth rate, Horticultural crops, NHM, and Structural break

The prominence being given to the sector was reflected through National Horticulture Mission (NHM). The principles of the Mission were area-based, regionally differentiated cluster approach for the development of horticultural crops, having comparative advantage (Doddamani *et al.*, 2014). Due to implementation of mission there has been upward trend in production of flowers, medicinal aromatic crops, spices, fruits, vegetables and plantation crops which contributes about 76, 55, 44, 42 and 31 per cent of increased production respectively from 2005-06 to 2019-20, as a result of substantial advancements in area expansion and the implementation of upgraded technologies (Patil and Hosamani, 2018).

MATERIALS AND METHODS

Considering the significant change in post NHM period, exponential growth function $Y_t = ab^t$ is used to estimating the annual compound growth rate of area, production and productivity of selected 15 crops and financial progress of NHM scheme.

The time series data on area, production and productivity of selected horticulture crops from 1997-98 to 2018-19 were collected from Horticultural and Agricultural Statistics at a Glance and various published sources. For the study 15 major crops were selected based on availability of data under five categories and they are high valued crops (banana, turmeric and cardamom), plantation crops (cashew nut, coconut and arecanut), vegetable crops (onion, chilly and coriander), spices crops (pepper, ginger and garlic) and tuber crops (tapioca, potato and sweet potato) during pre-NHM (1997-98 to 2004-05) and post-NHM (2005-06 to 2018-19) period launched in tenth five-year plan with effect from 2005-06.

In the log form, it is written as:

$$Log\ Y_t = Log\ a + t\ log\ b$$

where, Y_t = area / production / productivity in the year 't', t = time element which takes the value 1, 2, 3,... n, a = intercept and b = regression coefficient.

The value of b is computed by using OLS method. Further the value of CGR was worked out as follows:

$$CGR\ (r) = (antilog\ b - 1) \times 100$$

RESULTS AND DISCUSSION

An unanticipated shift in time series data causes a structural break. During the shift, the values of linear regression model's parameters do not remain constant and this could be due to external influences, major policy changes, or a variety of other factors. If breaks are not identified, a continuous analysis taking entire period may lead to forecast errors and may make the

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proposed model questionable. In this regard, break in the Clemente- Montañes-Reyes test (1998) was employed which estimates two endogenous structural breaks in the data series by using stata software. Based on identified structural break, CGR was computed for production of selected horticultural crops (Anbukkani *et al.,* 2017).

During 2005-06 to 2018-19, the scheme was being implemented in 537 districts covering 18 states and five Union Territories which is about 75 per cent of the total number of districts in country and it was supported by 20 National Level Agencies. The production of fruits, vegetables, flowers, plantation crops, spices, and medicinal and aromatic plants, were double fold during the mission. These results are consistent with the findings of Jadhav *et al.,* (2016) and Nabi and Bagalkoti (2017). The amount released and expenditures increased annually at the rate of 1.83 and 4.93 per cent respectively, from 2005-06 to 2018-19 (Table 1).

There has been a fluctuating pattern in utilization of funds throughout the NHM period. During the initial period, it was about 33.45% and increased to 90.24% in 2018-19. This could be owing to that most of the components were not correctly implemented in all states during the early stages, but that later on, all components became active. During the same period, total amount released and expenditure made were around ₹ 13410.50 and ₹ 12475.53 crores, respectively. The ratio of total spending to total funds sanctioned was projected to be 93.03 per cent, indicates the NHM scheme's success in India. The average amount released and expenditure made during the same time period was ₹ 957.89 and ₹ 891.11 crores, respectively. Patil and Hosamani (2017 and 2018) conducted a study that yielded similar results.

The current status and growth performance of NHM in India on selected horticultural crops been analyzed using Compound Growth Rate (CGR) for pre-NHM and post-NHM separately. The area, production and productivity of selected horticultural crops in India were found to be increased from pre-NHM to post-NHM are furnished in the Table 2. Among selected crops, high positive growths in area are noticed during post-NHM onion (6.62 per cent), garlic (6.61 per cent), banana (5.34 per cent), coriander (5.13 per cent), arecanut (5.02 per cent) ginger (4.39 per cent), and potato (3.56 per cent). Area under the crops such as banana, chilly, coriander, and sweet potato has negative growth rates in pre-NHM period and positive growth rates in post-NHM period. Conversely, pepper has positive a growth rate during pre-NHM but has negative significant growth in post-NHM which shows declining in pepper farming due to volatility in price and declining profitability (Sabu *et al.,* 2020).

In production, post-NHM period has highest growth rate in ginger (11.40 per cent), followed by coriander (10.29 per cent), onion (9.19 per cent), garlic (8.43 per cent), compared to pre-NHM period. Meanwhile, coconut, banana, sweet potato, and tapioca shows negative growth rate in pre-NHM period but recorded significantly positive growth during post-

Table 1. CGR (%) of selected horticulture crops - pre NHM vs post NHM period

Crop	Area		Production		Productivity	
	Pre -NHM	Post -NHM	Pre -NHM	Post -NHM	Pre -NHM	Post -NHM
Banana	-1.78	5.34*	-0.20*	5.97*	1.61*	1.70*
Turmeric	0.10*	2.22	0.50	2.53*	0.10	0.40*
Cardamom	1.41	0.60*	8.76*	5.34	5.97	7.36*
Onion	2.94	6.62*	5.65	9.20*	2.43*	2.53*
Chillies	-3.54*	0.50	2.22*	4.50*	5.97*	5.98*
Coriander	-4.30*	5.13*	0.70	10.30*	4.60*	4.92*
Coconut	0.90	1.51*	-2.66*	0.90*	-4.30*	0.10*
Cashewnut	2.84*	2.12	3.15	2.02*	3.45*	1.58*
Arecanut	2.32	5.02*	6.08	5.13*	1.01	2.74*
Pepper	2.33*	-6.11*	3.46*	2.50	1.11*	0.82*
Ginger	3.15*	4.39*	3.98	11.40*	0.80	6.72*
Garlic	3.98	6.61*	5.44	8.44*	1.51*	1.82*
Tapioca	1.78*	2.66*	-1.09	5.54*	0.70	2.86*
Potato	0.60	3.56*	0.60*	6.40*	0.10	0.84*
Sweet potato	-2.96	1.01*	-2.76*	3.56*	0.20*	2.53*

* indicates 5 per cent significance level

Source: Author's calculation based on data from Agricultural Statistics 2019.

NHM period. It was an indication for high demand for the commodities for both domestic consumption as well as exports. Moreover, declining growth during the post-NHM period for arecanut, cashewnut, cardamom and pepper clearly indicates that the fatigue in existing technologies.

So, there is a need for horticultural training and extension of postharvest protocols for diverse fruits and vegetables, fruit preservation, market-based agricultural practises, cultivar assortment, and increasing season must all be evaluated and modernised. Small farm businesses may be encouraged to pursue entrepreneurship using a specialised management method of significant varieties for distribution among farmers can be standardised. Screening and improvement of suitable covered surroundings and systems for disorder control (Bhunia, 2019).

Though, transfer of improved technologies has bought significant growth rate of yield during post-NHM period in cardamom (7.36 per cent), ginger (6.72 per cent), tapioca, sweet potato, arecanut, potato, turmeric and coconut. Most probably both pre- and post-NHM shows constant growth rate for chillies (5.97 per cent), coriander (4.92 per cent), onion (2.53 per cent), garlic (1.82 per cent), and banana (1.71 per cent). Besides, declining yield growth during post-NHM period occurred in cashewnut and pepper. Because, disease and drought have wrecked the farmers with production and productivity dropping to alarming levels (Cariappa and Chandel, 2020).

The change in area, production and productivity trend was analyzed using Clemente- Montañes-Reyes test method of structural break analysis for selected horticultural crops depicted in the Table 2. The shift in growth has been reported after 2005 in all the crops and this shows significant growth has been observed after NHM implementation. This was again reported through structural break in 2nd period. Modal value of area in first shift was observed 2007 and 2nd shift in 2011, 2012 and 2013 same as the modal value of production also found during 2007 in 1st shift and 2011, 2012 and 2013 in 2nd shift. The modal value of yield was reported during 2006 and 2007 in first shift and 2nd shift observed in 2013 and 2015. So, productivity jump was reported in recent period. However due to area effect significant shift in area trend in earlier itself. Hence yield effect has clearly increased after 2012.

In order to estimate the growth in area, production and productivity particularly before and after the identified structural break points, CGR was analyzed for production of selected horticultural crops. The highest growth rate was registered after the 1st and 2nd shift period in structural break which indicates after implementation of NHM. The 1st and 2nd shift period were due to area expansion and productivity effect respectively.

Most probably among high valued crops, particularly banana and cardamom depict positive growth during both the shift which revealed due to area extension as well as adoption of modern production technology by the mission. But turmeric

Table 2. Structural break of selected horticultural crops - 1997 to 2019

Crop	Area		Production		Yield	
	Break 1	Break 2	Break 1	Break 2	Break 1	Break 2
Banana	2007	2010	2007	2010	2003	2007
Turmeric	2007	2011	2006	2011	2006	2013
Cardamom	2008	2011	2011	2015	2012	2015
Onion	2007	2012	2007	2012	2006	2010
Chillies	2003	2008	2005	2013	2004	2013
Coriander	2009	2013	2010	2013	2010	2013
Coconut	2008	2012	2007	2012	2007	2010
Cashew nut	2006	2011	2005	2011	2005	2011
Arecanut	2004	2010	2006	2013	2008	2013
Pepper	2011	2013	2009	2015	2008	2015
Ginger	2007	2011	2007	2012	2007	2012
Garlic	2008	2013	2008	2013	2004	2010
Tapioca	2006	2013	2006	2013	2006	2015
Potato	2007	2011	2008	2011	2004	2013
Sweet potato	2007	2012	2007	2013	2009	2013

Source: Author's calculation based on data from Agricultural Statistics 2019.

production growth was increased 3.26 per cent during 1st shift and declined in 2nd shift with 2.32 per cent due to harsh weather condition during 2014-15 which has been reported by Sajjan *et al.*, (2018). The production of selected vegetable crops such as onion, chilly and coriander noticed that consistent increasing trend in 1st shift compared to 2nd shift period mainly due to diversification of crops from cereals to horticultural crops attributed to increased demand to vegetable and fruit crops (Kundu, 2012).

Whereas Bhat (2017) stated area expansion and improved varieties of selected plantation crops such as coconut, cashwenut and arecanut were observed significant increasing positive trend during structural changes. The presence of structural break period in production of selected spice crops (ginger and garlic) and tuber crops (potato and sweet potato) witnessed significant changes in growth. Besides, pepper and tapioca trend line shows declining growth during 2nd break period due to decline in prices, erratic climate, long crop duration, diseases and shrinkage in cultivated area have led to a decline in crop management leading to a drop in production (Prakash *et al.*, 2020 and Cariappa and Chandel, 2020).

It was observed that banana, onion, chilly, cardamom, cashewnut, ginger, garlic and potato registers higher annual compound growth in last 5-6 years may be due to area expansion by the NHM, adoption of recent released high-yielding varieties or saplings distributed through as a NHM components and expertise acquired by farmers.

CONCLUSION

The structural break analysis revealed that almost all selected crops production has recorded positive and significant growth rates during all the shift periods, except pepper and tapioca. Though, production of selected crops has increased from 2005-06, the area expansion began since 2007 due to NHM intervention. Despite having increasing trend, NHM should encourage its growers.

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Characterization of coriander *(Coriandrum sativum)* genotypes based on floral traits

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ABSTRACT

An experiment was conducted on 64 genotypes of coriander to characterize them for various morphological characters. On account of days to 50% flowering, [13 genotypes were grouped as early flowering (≤75 days), 38 as medium flowering (76-100 days) and 13 as late flowering (>100 days)]; based on corolla colour, [32 were grouped as white, 25 as pink and 7 as purple], based on visual observation of presence or absence of involucre, all genotypes were categorized into two groups, 59 showed the presence of involucre and only five genotypes were found without involucre. The arrangement of umbellets in umbel [29 were observed as loose umbel, 35 were observed as compact umbel]. While 17 genotype were classified as less umbel (≤100), medium umbel (100.1-150) and high umbel (>150)]. The 21 genotypes were categorized into less umbellet group (≤6) and 43 into more umbellet (>6) group. Two groups were formed based on number of seeds/umbellet, *viz.* 14 were grouped as less-seeded (≤6) genotypes and 50 as more seeded (>6) genotypes. Fourteen genotypes were found low yielder (≤45 g), 30 as medium yielder 45.1-60 g) and 20 genotypes as high-yielding (>60 g).

Key Words: Genotypes, Characterization, Involucre, Seed yield

Coriander (*Coriandrum sativum* L.) is well known spice crop through the world. Its Plant characterization is based on morphological, chemical, biochemical and molecular traits. Morphological characterization of a variety is based on morphological traits such as plant growth, stem, leaves, flower seed, *etc.* Different genotypes have variable desirable characteristics for growth, yield, quality, biotic and abiotic stress resistance. A large number of genotypes having varying plant characteristics have been identified and developed for coriander. Characterization of genotypes is necessary as it guides their further utilization in crop improvement programmes. Hence, an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, during 2013-2014 and in 2014-2015. Fifteen genotypes along with four contrast varieties were sown in each block. The net plot size was 3.0 m × 1.0 m and sowing was done at row-to-row and plant-to-plant spacing of 50 and 20 cm, respectively. The recommended package of practices were followed. Ten competitive plants from each plot were randomly selected for recording of data. The genotypes were grouped into early (≤75 days), medium (76-100 days) and late flowering (>100 days); corolla colour was observed visually as white, pink and purple; visual observation was recorded for the presence or absence of involucre and arrangement of umbellets/umbel on main umbel to characterize genotypes into loose or compact umbel.

The number of umbels/plants was recorded and genotypes were characterized into less (≤100), medium (100.1-150) and more umbel (<150). The number of umbellets/umbel was categorise as genotypes with less (≤6) and more (>6) number of umbellets/umbel. The genotypes were classified into less (≤6) or more (>6) number of seed/umbellate and seed yield/plant was recorded manually and genotypes were categorized as low (≤45 g), medium (45.1-60 g) and more yielder (>60 g).

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RESULTS AND DISCUSSION

All 64 genotypes were differentiated into three categories, *viz.* 13 as early flowering (≤75 days), 38 medium flowering (76-100 days) and 13 late flowering (>100 days). The data for days to 50% flowering ranged from 72 to 110 days. The earliest flowering was observed in DH-290 (72 days) and DH-313-1 (72 days), whereas late flowering genotypes were Hisar Bhoomit (110 days), followed by DH-304 (109 days). Awas *et al.* (2015) observed that days to 50% flowering ranged from 37 (accession 240560) to 79 days (accession 240547), followed by accession 240561 (77.5 days) and accession 240562 (76.5 days) respectively and calculated higher heritability (94.5%) for days to 50% flowering. Giridhar *et al.* (2014) reported that 10 genotypes for days taken to 50% flowering ranged from 51.3-63.1 days with LCC-236 as earliest flowering genotype.

Table 1. Categorization of coriander genotypes based on umbels/ plant, umbellets/umbel, seeds/umbellet and seed yield / plant (g)

Descriptor	Category	Entries	Genotypes
Umbels/plant	Less umbel (≤100)	17	DH-290, DH-292, DH-296, DH-297-2, DH-298, DH-302, DH-303, DH-303-1, DH-304, DH-306, DH-309, DH-316, DH-318, DH-319, DH-320, DH-321, DH-329
	Medium (100.1-150)	37	H. Anand, H. Surbhi, H. Sugandh, DH-291, DH-293-1, DH-293-2, DH-294-1, DH-294-2, DH-295, DH-297, DH-297-1, DH-301, DH-303-2, DH-304-1, DH-306-1, DH-307, DH-309-1, DH-309-2, DH-310, DH-311, DH-312, DH-313-1, DH-314, DH-315, DH-316-1, DH-317, DH-322, DH-325, DH-326, DH-327, DH-330, DH-331, DH-331-1, DH-332, DH-333, DH-333-1, DH-337
	High umbel (>150)	10	H. Bhoomit, DH-289, DH-293, DH-294, DH-305, DH-308, DH-313, DH-324, DH-336, DH-338
Umbellets/umbel	Less (≤6)	21	DH-290, DH-294-2, DH-295, DH-296, DH-297-1, DH-298, DH-302, DH-303, DH-303-1, DH-304, DH-306, DH-309, DH-313-1, DH-316, DH-318, DH-319, DH-320, DH-321, DH-329, DH-332, DH-336
	More (>6)	43	H. Anand, H. Surbhi, H. Sugandh, H. Bhoomit, DH-289, DH-291, DH-292, DH-293, DH-293-1, DH-293-2, DH-294, DH-294-1, DH-297, DH-297-2, DH-301, DH-303-2, DH-304-1, DH-305, DH-306-1, DH-307, DH-308, DH-309-1, DH-309-2, DH-310, DH-311, DH-312, DH-313, DH-314, DH-315, DH-316-1, DH-317, DH-322, DH-324, DH-325, DH-326, DH-327, DH-330, DH-331, DH-331-1, DH-333, DH-333-1, DH-337, DH-338
Seeds/umbellet	Less (≤6)	14	DH-296, DH-297-2, DH-298, DH-302, DH-309, DH-316, DH-319, DH-320, DH-321, DH-322, DH-324, DH-325, DH-329, DH-333-1
	More (>6)	50	H. Anand, H. Surbhi, H.Sugandh, H. Bhoomit, DH-289, DH-290, DH-291, DH-292, DH-293, DH-293-1, DH-293-2, DH-294, DH-294-1, DH-294-2, DH-295, DH-297, DH-297-1, DH-301, DH-303, DH-303-1, DH-303-2, DH-304, DH-304-1, DH-305, DH-306, DH-306-1, DH-307, DH-308, DH-309-1, DH-309-2, DH-310, DH-311, DH-312, DH-313, DH-313-1, DH-314, DH-315, DH-316-1, DH-317, DH-318, DH-326, DH-327, DH-330, DH-331, DH-331-1, DH-332, DH-333, DH-336, DH-337, DH-338
Seed yield/plant (g)	Low (<45 g)	14	DH-290, DH-296, DH-298, DH-302, DH-303, DH-303-1, DH-306, DH-309, DH-316, DH-318, DH-319, DH-320, DH-321, DH-329
	Medium (45.1-60 g)	30	H. Surbhi, H. Sugandh, DH-292, DH-293-1, DH-293-2, DH-294-2, DH-295, DH-297, DH-297-1, DH-297-2, DH-301, DH-304, DH-304-1, DH-306-1, DH-307, DH-309-1, DH-309-2, DH-316-1, DH-317, DH-322, DH-324, DH-325, DH-326, DH-327, DH-330, DH-331, DH-331-1, DH-332, DH-333-1, DH-337
	High (>60 g)	20	H. Anand, H. Bhoomit, DH-289, DH-291, DH-293, DH-294, DH-294-1, DH-303-2, DH-305, DH-308, DH-310, DH-311, DH-312, DH-313, DH-313-1, DH-314, DH-315, DH-333, DH-336, DH-338

Arif *et al.* (2014) mentioned that days to flower initiation were positively correlated to days to harvesting. Devi *et al.* (2017) also observed negative heterosis for days to 50% flowering in 28 cross combination of okra lines. Corolla colour was observed visually and all genotypes were classified into three groups, *i.e* 32 showed white colour of corolla, 25 pink colour while seven showed purple colour. Rai (2014) characterized 50 American cotton genotypes on basis of petal colour in three categories.

All genotypes were categorized into two groups, *i.e.,* 59 showed the presence of involucre and only five were found without involucre. All genotypes were categorized into two categories, *i.e.* loose umbel type (29 genotypes) and compact umbel type (35 genotypes). Similarly, Amit (2012) classified 60 coriander genotypes into corymb (31 genotypes) and non-corymb (29 genotypes) type of umbellet arrangement. All genotypes were categorized into three groups, *i.e.* 17 were grouped as less umbel (≤100), 37 as medium umbel (100.1-150.0) and ten as high umbel (>150) group.

Awas *et al.* (2015) reported variation in umbel/plant (20.65-60.10), showing wide variability among accessions. Accession 212830 gave highest umbel number/plant (60.1), followed by accession 242241 and 90304 (59.7 and 56.3, respectively). Twenty-one genotypes were categorized into less umbellet group (≤6) and 43 into more umbellet (>6) group. Awas *et al.* (2015) reported a low variability among genotypes for umbellets per umbel as compared to other traits. Accession 90311 had highest number of umbellets/umbel (8.2), followed by accession 90312 and 208766 (7.5 and 7.3, respectively).

Accession 230576 and 242918 gave lowest number of umbellets/umbel (4.4 and 4.9, respectively). Singh and Dubey (2015) also observed significant variability in 19 garlic genotypes for clove/bulb. The number of seeds/umbellet of all genotypes varied from 4.6 to 9.6. Minimum number of seeds/umbellets was found in DH-329 (4.6) and highest seeds/umbellet obtained in DH-291 (9.6), followed by DH-294 (9.2). Neelavathi *et. al.* (2015) found significant variations among small bitter gourd genotypes for number of fruits/plants and number of seeds/fruit evaluated in all three seasons. Similar variations were observed by Choudhary *et al.* (2016) for number of seed/fruit among 10 genotypes of watermelon (Table 1).

Lowest seed yield/plant was obtained in DH-320 (30.8 g) and highest seed yield/plant was obtained in DH-294 (84 g), followed by DH-313 (83.2 g). Awas *et al.* (2015) observed the range for seed yield per plant was 1.5-14.5 g with a mean value of 7.62 g. Accession 212830 gave highest seed yield/plant (14.5 g), followed by accession 90304 (13 g) and accession 240552 (12.5 g). The lowest seed yield/plant was registered for accession 90307 and 207516 (1.5 g).

CONCLUSION

The genotypes, Hisar Bhoomit, DH-289, DH-293, DH-294, DH-294-1, DH-305, DH-308, DH-313, DH-333 and DH-338, showed superiority for almost all umbel and yield based characters.

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Effect of organic and inorganic sources of nutrition on productivity and economics of tomato *(Lycopersicum esculentum)* in Varanasi

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ABSTRACT

A field experiment was conducted during winter season of 2016- 2017 to find out the effect of different organic and inorganic sources of nutrition on growth, productivity and economics of tomato cultivation in Varanasi region. The organic sources of fertilizer were farmyard manure (FYM), poultry manure (PM), vermicompost (VC) with three levels of each and one chemical fertilizer dose applied as 100% RDF of NPK. The chemical fertilizer (CF) was applied at recommended dose of 180:60:60 kg/ha of N:P_2O_5:K_2O. The application of 10 t poultry manure/ha recorded maximum growth and fruit yield (584.69 q/ha), which was significantly superior to its own lower levels of poultry manure and rest of organic manures as well as inorganically cultivated tomato crop, *i.e.* 100% RDF of NPK through chemical fertilizer. However, higher levels of each organic manure gave significantly higher growth and fruit yield. Lowest net return was observed with treatment (VC: 2.5, t vermicompost/ha). Crop alimentation of tomato by supplying 10 t PM/ha recorded highest benefit:cost ratio (3.39) among organic sources. While, within organic and inorganic sources; application of RDF of NPK through chemical fertilizer recorded quite lesser benefit:cost ratio (3.36) than organically grown tomato.

Key Words: Tomato, Organic manures, FYM, PM, VC, Chemical fertilizer, Fruit yield, Economics

Variations in tomato (*Lycopersicum esculentum* L.) growth and yield might be due to differences in nutrient management under similar as well as varying agro-climatic conditions. However, limited information is available on tomato growth and yield under varying nutrient management systems in Varanasi region. Therefore, comparative assessment of effect of different organic and chemical fertilizer sources on tomato growth and yield was done.

MATERIALS AND METHODS

The experiment was conducted during winter season from mid-September to mid-March, in a randomized complete block design and replicated three times as per treatment with the plot sizes of gross and net were 2.25 m 4.2 m and 1.8 m 3.6 m, respectively. Shade dried FYM, PM and VC were assembled and applied on dry weight basis on a month prior to planting and thoroughly mixed with soil. The plots with inorganic treatment were fertilized by urea, diammonium phosphate, and MOP as half of nitrogen and potash and full dose of phosphorus applied at the time of bed preparation. The remaining doses were applied when flowering initiated. Transplanting of seedling was done at 8th November 2016, followed by one light irrigation at the same time and second one 4th day after transplanting. Two manual hand weeding, first at 35 DAT and second along with earthing up done at 60 DAT to manage weeds in crop, followed by staking operation carried out. Plant protection practices were carried out as per requirement.

All treatments were grouped into two organic and inorganic nutrient systems, consisting of three nutrient sources with three levels of each, *viz.* FYM (10, 20, and 30t ha^{-1}), poultry manure (PM: 5.0, 7.5 and 10 t/ha), vermicompost (VC: 2.5, 5.0 and 7.5t/ha) and another one inorganic source as recommended dose of N, P_2O_5 and K_2O (180: 60: 60) for hybrid tomato was applied through inorganic fertilizers.

In inorganic source, recommended dose of N, P, K is supplied through chemical fertilizer were urea (46%

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N), diammonium phosphate (DAP: 46% P_2O_5 and 18% N), and MOP (60% K_2O). Seedlings of Kashi Vishesh (F_1 hybrid : H-86) characterized as resistant to tomato leaf curl virus (ToLCV), developed from IIVR, Varanasi by using *Lycopersicum hirsutum* f. *glabratum* B'6013' × Sel 7 as donor parent following backcross pedigree selection method, plants determinate, dark green, fruits are red with spherical in shape, size medium to large, average fruit weight 80 g with yield potential of 400-450q/ha.

Data on growth parameters were collected at 30, 60, 90 DAT. While, yield was calculated by adding all the fruit weights as per treatments obtained during different pickings. The data were analyzed by adopting appropriate Model "Analysis of variance" as per procedure described by Panse and Sukhatme (1967). Critical difference (CD) for the treatments was calculated in order to compare the treatments at 1% and 5% level of significance.

RESULTS AND DISCUSSION

The treatment receiving 10 t/ha of poultry manure showed highest growth at both the stages, *viz*. 60 and 90 DAT, similar result were found by Geetharani and Parthiban (2014). Although, higher doses of organic manures significantly recorded higher growth at all the stages of cropping season as compared to lower levels of organic manures. In general, application of poultry manure recorded taller plants as compared to FYM or vermicompost. The plant height under control (inorganic system) was significantly comparable to those under FYM @ 20.0 and 30.0 t/ha, poultry manure @ 7.5 and 10 t/ha as well as vermicompost @ 7.5 t/ha at 60 DAT, while at 90 DAT only treatment receiving 10 t/ha of poultry manure significantly recorded higher plant height than RDF of inorganic fertilizer. The higher number of green leaves significantly recorded with higher levels of organic manure than lower levels of manure under organic nutrient supply system.

Under organic and inorganic system, different organic manures at different levels showed significantly higher green leaf counts than recommended dose of inorganic fertilizer except FYM @ 10 t/ha and VC @ 2.5 and 5.0 t/haat 60 DAT and FYM @ 10 t/ha and all levels of vermicompost at 90 DAT as they failed to touch the level of significance. There was a significant response to different organic manures as well as their doses to leaf sizes at 60 and 90 days after transplanting. At 60 days stage, smallest leaves (leaf length × leaf width: 20.19 cm × 12.69 cm) were observed under lowest dose of (vermicompost @ 2.5 t/ha). However, it was at par to FYM @ 10.0 t/ha. At this stage, leaf sizes was maximum (22.69 cm × 16.99 cm) under poultry manure source @ 10.0 t/ha which was highly significant to all other treatments. With the advancement of the growth stage, *i.e.* 90 days, leaf size increased considerably in all the treatments. However, growth pattern was more or less similar to that of 60 days after planting.

The leaf size was maximum (23.39 cm × 17.29 cm) under poultry manure applied @ 10.0 t/ha and minimum (20.39 cm × 14.09 cm) under lowest dose of vermicompost@ 2.5 t/ha.

The maximum number of nodes (12.19) at 60 DAT was found with the application of poultry manure @ 10.0 t/ha. The minimum number of nodes (7.19 cm) was recorded under treatment receiving vermicompost @ 2.5 t/ha. At 90 days of planting.

The number of branches varied from 10.39 under lowest level of vermicompost, *i.e.* @ 2.5 t/ha to 12.89 under highest level of poultry manures @ 10 t/ha. The number of branches under inorganic nutrient supply system (control) was significantly lower to that under FYM @ 30.0 t/haand poultry manure @ 7.5 and 10 t/ha, while nutrient supplied to crop by FYM@ 10 and 20 t/ha and all the vermicompost manure. However, growth pattern remained almost similar to that at 60 days of planting. At 90 days growth stage, the number of branches ranged from 12.29 under vermicompost @ 2.5 t/hato 14.29 under poultry manure @ 10.0 t/ha.

Application of 10 t/ha poultry manure recorded maximum stem diameter (0.91 cm) at 60 DAT, which is significantly higher to lower levels of poultry manure. The minimum stem diameter (0.63 cm) was recorded with lowest level of vermicompost @ 2.5 t/ha. The organic nutrient sources were able to create significant differences in relation to mean stem diameter than inorganic nutrient supply system, *i.e.* 100% RD of NPK through inorganic fertilizer (IF) (control).

The higher plant height, green leaf count, leaf sizes, number of nodes and branches and mean stem diameter were recorded under poultry manure. There was superiority of poultry manure over other two other organic manures (Acharya and Kumar 2018).

The average fruit weight (80.10 g), fruit number (20.79/plant), fruit yield (1.67 kg/plant) as well as highest fruit yield (584.69 q/ha) were recorded under treatment receiving poultry manure @ 10 t/ha. Supplying of poultry manure @ 10 t/ha recorded 46.18% higher fruit yield q/ha than the control, *i.e.* 100% RD of NPK through IF (399.99 q/ha). The FYM and vermicompost showed significant ($p>0.05$) increase in average fruit weight, fruit numbers and fruit yield/plant as well as total fruit yield. These results are in conformity with the findings of Pandey and Chandra, 2013; Kalbani *et al.*, 2016; Yadav *et al.*, 2016.

The organic manures namely FYM (@ 30 t/ha) and poultry manure (@ 7.5 and 10 t/ha) recorded significantly superior average fruit weight, fruit number

and fruit yield / plant as well as total fruit yield to inorganic fertilizer. Wherever, vermicompost recorded statistically at par performance to inorganic fertilizer, which might be due to lower doses of vermicompost in comparison to other organic manures. The weight of fruit, fruit number and fruit yield / plant were directly influenced by enhanced vegetative growth, *viz*. significant increase in height, number of branches, number of green leaves and size (length and width) of leaves as influenced by organic treatments. Maximum cost of cultivation (₹ 224404.80) was estimated in T_3 (30 t FYM / ha) and lowest in T_{10} (180,60,60 kg NPK / ha through chemical fertilizer) and T_7 (2.5 t VC / ha) which, respectively accounted for just ₹ 137589.24 / ha and ₹ 147804.80 / ha.

Application of poultry manure @ 10 t / ha fetches higher net income than all other sources. Therefore, it was concluded that among different sources of plant nutrients (10t PM / ha) proved more profitable in terms of economic benefits. Similar reports were mentioned by Magray *et al.* (2013).

The highest net return is with PM @ 10 t / ha is possibly due to comparatively lesser total cost of cultivation and utmost yield with this treatment. Superiority of poultry manure in enhancing yield of tomato is richness in nutrition, besides having narrow C:N ratio and thus more decomposition, helping in increasing the availability of nutrients (Magray *et al.* 2013).

CONCLUSION

The application of organic manures for nutrient management in tomato variety Kashi-Vishesh, showed best profitable output over inorganic nutrient management. Considering organic and inorganic sources, there is significant transcendency of organic sources over inorganic nutrient management in tomato crop.

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Decipheration of flowering and fruiting characters in phalsa *(Grewia subinaequalis)* germplasm under semi-arid region of Haryana

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ABSTRACT

A field experiment was conducted at CCS Haryana Agricultural University, RRS, Bawal (Rewari), Haryana, on 13 genotypes (4 tall double-seeded, 6 tall single-seeded, 3 dwarf-single seeded) of phalsa having a wide range of variability in flowering and fruiting traits in randomized block design, during 2018-19. The number of flowers/inflorescence varied from 3 to 4 in Bawal Phalsa 1, Bawal Phalsa 2, Bawal Phalsa 3, Bawal Phalsa 4, Bawal Phalsa 5, Bawal Phalsa 6, Bawal Phalsa 7, Bawal Phalsa 8, Bawal Phalsa 9 and Bawal Phalsa 10. However, 2 to 5 flowers/inflorescence were observed in dwarf germplasm. Early flowering was found in tall double-seeded germplasm, whereas end of flowering and fruit maturity exhibited early in dwarf germplasm. The fruit length, breadth, and weight were maximum in Bawal Phalsa 4, minimum in Bawal Phalsa 12, whereas number of fruits picking were maximum in Bawal Phalsa 5 and minimum in Bawal Phalsa 1. Fruit shape was globose type in Bawal Phalsa 1, Bawal Phalsa 2, Bawal Phalsa 3 and Bawal Phalsa 4, whereas round in Bawal Phalsa 5, Bawal Phalsa 6, Bawal Phalsa 7, Bawal Phalsa 8, Bawal Phalsa 9, Bawal Phalsa 10 and dwarf germplasm. Fruit skin colour was purple in tall double-seeded, whereas deep purple in tall single-seeded and dwarf germplasm. Fruit lobe was present only in tall double-seeded germplasm. Inflorscence type and petal colour showed no variation.

Key Words: Germplasm, Single-seeded, Double-seeded, Flowers and Fruit

Phalsa (*Grewia subinaequalis* DC.) is an important underutilized fruit of India and Southern Asia. An enormous variability with respect to yield, qualitative and quantitative character in different fruit crops (Sharma *et al.,* 2015). In different bael germplasm, (Singh *et al.*, 2018) studied morphological, floral and phenological behaviour. These morpholo-gical traits are primary markers utilized in germplasm management (Kumar *et al.,* 2016). Based on growth, yield and quality performance of different germplasm, the suitable germplasm can be selected. Hence an experiment was conducted to find out most suitable & germplasm.

MATERIALS AND METHODS

The field experiment was conducted at CCS Haryana Agricultural University, Regional Research Station, Bawal (Rewari) during 2018-19. The 39-year old phalsa trees planted at 3m × 3m spacing, uniformly grown plants were selected, earmarked based on visual differences during January, 2018 and maintained under uniform conditions of orchard management. All recomended package of practices were followed in randomized block design with three replications. Uniformly ripen fruits free from any injury or diseases were harvested for estimation. Inflorescence were recorded at appropriate growth stages, as per descriptor of NBPGR and guidelines for DUS testing of PPV and FRA (PPV&FRA, 2016). The petal and fruit skin colour were observed visually at appropriate stage as per standard colour chart.

Date of start of flowering was noted when five per cent flower buds of tagged branches were open while date of end of flowering was noted when 85-90 per cent flower buds on tagged branches were open and date of 50 per cent of fruits maturity was noted when 50 per cent fruits attained maturity on tagged branches. Five inflorescences were selected randomly from each direction of the plant and numbers of flowers in each inflorescence were counted manually and mean value

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was worked out. The ripen fruits were picked for different purposes and the number of pickings of fruits was counted and recorded manually from first picking to last picking.

Five fruits from each direction of a plant were collected than fruit length and fruit breadths were measured with the help of digital Vernier Callipers and average value was taken and expressed in millimeter. Five randomly selected fruits from different directions of the plant were picked, their weight was noted and average fruit weight was expressed in gram. The shape of fruits was observed as round, globose and others based on curvature at the distal end of fruit. Fruit lobe was observed visually and categorized as present or absent.

RESULTS AND DISCUSSION

The initiation of the flower was early (19-26 March) in Bawal Phalsa 3, whereas comparatively late (2-7 April) in Bawal Phalsa 12. The period of the end of flowering (85-90% flower open) was observed from 17 April to 30 April. Flowering was ended early (17-23 April) in Bawal Phalsa 13, whereas it was delayed in Bawal Phalsa 2, *i.e.,* 28 April to 30 April. Aulakh *et al.* (2013), Bakshi *et al.* (2015) and Kotiyal *et al.* (2015) observed initiation of flowering in aonla in April.

The phenological response of phalsa in terms of early flowering is considered among prominent biological indicators of climatic conditions. Since winter is not intense in tropics, flowering event in phalsa seems to be influenced by age of shoot rather than low temperature and prevalence of mild winter attribute to advance and asynchronous flowering, *i.e.* November to February. On the other hand, low temperature might be critical factor for flower induction in subtropical regions, as flowering takes place in spring season just after winter within a short range of duration, *i.e.,* March-April. The period of 50 per cent fruit maturity was observed earliest in Bawal Phalsa 13 (5-9 May), followed by Bawal Phalsa 11 (6-10 May) and late in Bawal Phalsa 4 (20-24 May). This may be due to equirement of environmental / physiological conditions a particular germplasm. Such a type of variation in fruit maturity was also found by Dhaliwal *et al.* (2012), Aulakh *et al.* (2013), Bakshi *et al.* (2015).

There was no significant variation in pattern of inflorescence. The inflorescence type of all germplasm was observed as an axillary cyme. A similar type of inflorescence was also found by those of Haq *et al.* (2013) and Sinha *et al*. (2015). The number of flowers / inflorescence varied from 3 to 4 flowers / inflorescence in tall double-seeded and tall single-seeded germplasm, however, 2 to 5 flowers / inflorescence were observed in dwarf germplasm. These types of variation regarding the number of flowers per inflorescence in phalsa were also observed by Mishra *et al*. (2018). This variation in inflorescence type and the number of inflorescences might be due to genetic makeup of germplasmThere were no clear differences among different germplasm regarding petal colour *i.e.,* all germplasm have the dull yellow colour of petal. These similarities might be due to a close relation in the genetic background of germplasm. Mishra *et al.* (2018) observed pale yellow to greenish yellow colour of petal.

The number of fruit pickings ranged from 3.33 in Bawal Phalsa 1 to 7.33 in Bawal Phalsa 5 (Table 1). The maximum number of fruit picking was in Bawal Phalsa 5 (7.33), while minimum in Bawal Phalsa 1 (3.33). The variation in number of pickings may be due to ripening conditions of fruits remains for the longer period after maturity, however, in less number of picking favourable conditions may remain available for a shorter period. The 50 per cent maturity in fruits was also delayed in germplasm recorded less number of pickings means environmental conditions for ripening available for a limited period. Maximum fruit length (20.56 mm) found in Bawal Phalsa 4 and lowest (11.99 mm) in Bawal Phalsa 12 (Table 1). The fruit breadth varied significantly in different germplasm and ranged from 9.97 mm to 19.60 mm (Table 1). The highest fruit breadth (19.60 mm) found in Bawal Phalsa 4 and lowest (9.97 mm) in Bawal Phalsa 12. These types of variation in fruit length and breadth of phalsa were also found by those of Haq *et al.* (2013).

The difference in length and breadth might be due to the genetic features of a particular germplasm. The fruits of germplasm had higher fruit size (length and breadth) may be due to fruits remained on plant for more time to attain maturity as well as ripening. The highest fruit weight (0.98 g) was recorded in Bawal Phalsa 4, which is at par with Bawal Phalsa 3, whereas lowest fruit weight (0.50 g) was recorded in Bawal Phalsa 12 (Table 1). The difference in fruit weight among the genotypes might be due to differences in number of seeds per fruit. These types of variation in fruit weight were also reported by Lal *et al.,* (2021), Mishra and Deen (2015) and Mishra *et al.* (2018). However, Haq *et al.* (2013) observed fruit weight between 0.5 g to 2.2 g. The fruits having higher weight also had more size. This may be due to fruits remained on plant for longer period for maturity as well ripening. The increase in fruit weight might be due to more uptakes of nutrients, water and translocation of photosynthates from source to sink. Fertility status of soils, microclimate and inherent characters of germplasm may be the other probable reason for these variations. Higher fruit weight is also preferred character for germplasm selection. The round fruit

Table 1. Fruit morphology of phalsa germplasm under semi-arid conditions of Haryana

Germplasm	Number of fruit pickings	Fruit length (mm)	Fruit breadth (mm)	Fruit weight (g)	Fruit shape	Fruit skin colour	Fruit lobe
Bawal Phalsa 1	3.33	18.88	18.44	0.87	Globose	Purple	Present
Bawal Phalsa 2	3.67	19.24	18.32	0.88	Globose	Purple	Present
Bawal Phalsa 3	4.00	19.60	18.68	0.89	Globose	Purple	Present
Bawal Phalsa 4	3.33	20.56	19.60	0.98	Globose	Purple	Present
Bawal Phalsa 5	7.33	16.23	15.86	0.62	Round	Deep Purple	Absent
Bawal Phalsa 6	6.33	16.92	15.96	0.67	Round	Deep Purple	Absent
Bawal Phalsa 7	6.33	16.18	15.45	0.73	Round	Deep Purple	Absent
Bawal Phalsa 8	7.00	16.97	15.76	0.72	Round	Deep Purple	Absent
Bawal Phalsa 9	6.33	16.02	15.24	0.73	Round	Deep Purple	Absent
Bawal Phalsa 10	6.67	16.96	15.78	0.69	Round	Deep Purple	Absent
Bawal Phalsa 11	7.00	12.58	10.78	0.54	Round	Deep Purple	Absent
Bawal Phalsa 12	6.33	11.99	9.97	0.51	Round	Deep Purple	Absent
Bawal Phalsa 13	6.00	12.89	10.15	0.52	Round	Deep Purple	Absent
CD (5%)	1.19	0.48	0.55	0.09	--	--	--
Range	3.33-7.33	11.99-20.56	9.97-19.60	0.51-0.98	--	--	--

shape was observed in tall single-seeded and dwarf germplasm, while globose fruit shape was observed in double-seeded germplasm (Table 1). The round-shaped fruits had one seed / fruit, but the globose shaped fruits had two seeds / fruit. The variation in shape might be due to variability in number of seeds per fruit. These variations may also be due to genetic characteristics of germplasm. However, Haq *et al.* (2013) and Singh *et al.* (2018) observed that globose type of fruits, whereas Mishra *et al.* (2018) observed round type of fruits. The deep purple fruit skin was observed in tall single-seeded and dwarf germplasm, while purple fruit skin was observed in tall double-seeded germplasm (Table 1). These types of variation in skin colour of fruit of phalsa were also reported by Haq *et al.* (2013) and Sharma *et al.*, (2015). Variations in fruit colour in different germplasm might be due to genetic background, climatic condition and nutritional status of fruit. Selection of cultivar for processing into different kind of products also depends on their appearance and other physical properties as they affect the look and quality of the end product. However, Mishra *et al.* (2018) observed deep reddish brown colour of phalsa fruits. Fruit lobe was present in all tall double-seeded germplasm, whereas it was absent in tall single-seeded and dwarf germplasm.

CONCLUSION

The germplasm was grouped into tall double-seeded, tall single-seeded and dwarf (single- seeded). Early flowering was observed in tall double-seeded germplasm, whereas flowering and fruit maturity were early in dwarf germplasm. Fruits with globose shape, purple skin colour and persistent lobe were reported in tall-double-seeded germplasm, while fruits with round shape, deep purple skin colour without lobe in tall-single seeded and dwarf germplasm.

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Optimization of NPK for curd yield in broccoli *(Brassica oleracea)* under middle Gujarat condition

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ABSTRACT

The experiment was conducted to optimise doses of NPK for curd yield in broccoli during *rabi* 2018-19, 2019-20 and 2020-21. There were 3 factors *i.e.* nitrogen @ 100, 150 and 200 kg/ha, phosphorus and potash each @ 50 & 75 kg/ha comprising 12 treatments. Significant increase was found in plant height, plant spread, number of leaves/plant, stem diameter, leaf length, curd weight, curd length, curd diameter, yield /plot, curd yield. The decrease in days to 50% in curd formation and days to final harvest were recorded with different levels of NPK doses. Growth and yield attributes were maximum with 200:75:50 NPK kg/ha which was at par with 150:75:50 NPK kg/ha.

KEY WORDS: Curd, NPK, Growth and yield parameters

Macro nutrients play an important role in growth and development of plant. Nitrogen encourages vegetative growth and phosphorus encourages root development, providing energy by forming ATP and potassium play an important for carbohydrate metabolism, enzyme activation and osmotic regulation (Shaheen *et al.,* 2007). The balanced fertilization of macro nutrients is essential for high yield and quality products. Middle Gujarat is bestowed with climate suitable for growing cool season vegetables in winter season. There is no standard dose of broccoli available for particular region. Therefore, experiment was conducted to study the Optimization of NPK requirement for growth and curd yield of broccoli under middle Gujarat condition.

MATERIALS AND METHODS

The experiment was conducted at College of Agriculture, Anand Agricultural University, Vaso (Gujarat). The soil of experiment was having pH-7.3, EC-1.28 dS/m, OC-0.56%, available NPK-180.0, 48.0, 248.0 kg/ha, respectively. The cultivar used in this experiment was Pusa KTS-1. Treatments comprised 3 levels of nitrogen (100, 150, 200 kg/ha), 2 levels each of phosphorus and potash (50 and 75 kg/ha). The experiment was laid out in factorial randomized block design with three replications. Application of fertilizers were given by urea, SSP and MOP. Urea was given in two equal split, first half before transplanting and second half 30 days after transplanting. Full dose of SSP & MOP were applied before transplanting. FYM @ 10 t/ha applied before transplanting. The observations were recorded on plant height (cm), plant spread N-S (cm), plant spread E-W (cm), number of leaves per plant, stem diameter (mm), stalk length (cm), leaf length (cm), days to 50% curd formation, days to first harvesting, days to final harvesting, curd weight (g), curd length (cm), curd diameter (cm), yield per plot (kg) and yield per hectare (t) as per standard method.

RESULTS AND DISCUSSION

The plant height, plant spread (N-S), plant spread (E-W), number of leaves /plant, stem diameter and leaf length increased significantly with higher dose of nitrogen. These all parameters were maximum with nitrogen @ 200 kg/ha while plant height, number of leaves/plant and stem diameter remained at par with nitrogen @ 150 kg/ha. This increased growth parameters may be due to nitrogen which has a major

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Table 1. Effect of N, P and K on yield parameters of broccoli 2018-19, 2019-20 and 2020-21 (pooled)

Treatment	Days to 50% curd formation	Days to first harvest	Days to final harvest	Curd weight (g)	Curd length (cm)	Curd diameter (cm)	Yield per plot (kg)	Curd yield (t/ha)
(A) Nitrogen levels								
N_1: 100 kg N/ha	38.93	56.01	62.79	380.63	15.82	17.87	7.65	15.74
N_2: 150 kg N/ha	40.32	58.14	66.09	455.22	18.34	19.74	8.82	18.15
N3: 200 kg N/ha	41.48	58.37	67.43	484.71	19.05	21.10	9.36	19.26
CD (5%)	1.58	NS	NS	50.47	0.47	NS	0.92	1.90
(B) Phosphorus levels								
P_1: 50 kg P_2O_5/ha	40.31	57.27	64.80	429.89	17.19	19.18	8.41	17.31
P_2: 75 kg P2O5/ha	40.18	57.74	66.07	450.48	18.29	19.96	8.81	18.13
CD (5%)	NS	NS	0.48	NS	NS	0.41	0.20	0.40
(C) Potash levels								
K_1: 50 kg K_2O/ha	40.10	57.40	65.28	432.29	17.32	18.98	8.56	17.62
K_2: 75 kg K_2O /ha	40.39	57.62	65.59	448.08	18.16	20.16	8.66	17.81
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS

role in vegetative growth. Nitrogen synthesizes proteins and formed the carbohydrates in plant favouring plant height and number of leaves. However, stalk length was found non-significant with nitrogen.

The curd weight, curd length, yield / plot & yield / ha increased significantly with nitrogen and found maximum with nitrogen @ 200 kg / ha which was at par with nitrogen @ 150 kg / ha. This might be due to increase in dry matter by more vegetative growth due to nitrogen. Proper utilization of carbohydrates, proteins and accumulation photosynthates and functions like carbohydrate metabolism and enzyme activation and translocation of sugars and starch by supply of optimum level of NPK and boron in broccoli. The days to 50% curd formation was significantly minimum with nitrogen @ 100 kg / ha which was at par with nitrogen @ 150 kg / ha. Days to first harvesting, days to final harvesting and curd diameter were non-significant (Table-1). Decrease in number of days to 50% flowering and final harvesting might be due to lower dose of nitrogen which imparts lower vegetative growth and early reproductive phase. These findings relates to (Saha et al., 2006; Moniruzzaman et al., 2007; Kumar et al., 2007).

Phosphorus @ 75 kg / ha recorded significantly maximum plant height, plant spread and number of leaves / plant, while stem diameter, stalk length and leaf length were non-significant with phosphorus application.

Curd diameter, yield / plot and yield / ha were significantly maximum with phosphorus @ 75 kg / ha. Minimum number of days to final harvesting was found with phosphorus @ 50 kg / ha. This might be due to phosphorus because it involves in cell division and development of meristematic tissue, thus improving better vegetative growth, root growth and development. Days to 50% curd formation, days to first harvesting, curd weight and curd length were non-significant with phosphorus. Growth and yield were found non-significant with potash treatment. These findings relates to those of (Ouda and Mahadeen, Kumar *et al.*, 2007). Thus farmers of middle Gujarat are recommended to apply 150 kg N, 75 kg P_2O_5, 50 kg K_2O / ha with 10 t FYM. Among them 150 kg N should be applied in split, *i.e.* 75 kg N at the time of transplanting and remaining 75 kg N at 30 days after transplanting for higher yield and net return.

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Short Communication

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Propagation of acid lime *(Citrus aurantifolia)* through nucellar seedlings: farmers perception

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Citrus (*Citrus* spp.) fruits, which include mandarin, sweet oranges, lemon, lime, pummelo etc., are primarily consumed as fresh fruits and also processed, mainly to prepare squash, juice, marmalade and pickles (Tripathi *et al.* 2018). Acid lime *(Citrus aurantifolia* Swingle*)* is commercially cultivated in Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat and Bihar. Acid lime or kagzi lime is a small tree of staggering habit with small, round or oval, greenish yellow fruits and is commercially propagated by seeds in India, as it comes true-to-type because of high degree (39-60%) of nucellar embryony and least chance of contamination of viral diseases, besides seed propagation being the economical and easiest method (Mukundalakshmi *et al.*, 2016).

Acid lime cultivars produce polyembryonic seeds where each seed can have multiple embryos, of which only one is the sexual or zygotic embryo and the other embryos are called nucellar embryos because they arise spontaneously from nucellar tissue in the seed. Since these nucellar embryos do not arise from sexual union, they are asexual and exclusively maternal in origin, i.e. their genetic make-up is identical to that of the mother plant.

Mortality of seedling is less as the seedlings of citrus are generally free from viruses, but the pre-bearing period (4-5 years for first fruiting) in seedling raised plants is higher. These seedlings have a tap root system and furnish better orchard stalks than vegetatively propagated budlings, which have only small secondary root system and therefore do not develop strong root system. The overall performance of kagzi lime seedling is better over budded plants. In India, so far only Gajanimma (*Citrus pennivesiculata* Tanaka) at Kodur, in Andhra Pradesh and recently Alemow (*Citrus macrophylla* Wester) at CCRI, Nagpur (Sonkar *et al.*, 2011) have been reported as promising rootstocks for acid lime.

Citrus propagation through budding method is among the most important limiting factor in generating them, since it leads to thread of various viral and virus-like diseases through generation of infected seedling. The other issue which is important in rootstock is their uniformity and propagation from seeds may not lead to production of uniform rootstock and though some of the rootstocks are produced by the nucellar embryos which are uniform and similar to mother plant, there are also plants produced by natural embryos which are not completely similar to the mother plant and this can lead to lack of uniformity among the rootstocks produced. Hence, in rootstock production, methods should ensure virus-free rootstocks, and uniformity as well.

Acid limes, being highly susceptible to tristeza virus that are graft transmissible and deploying a root stock for its cultivation in the absence of viable method and also a cost-effective technology for bud wood certification has not been popularised for large scale multiplication till to date. Plants of *C. aurantium* plants showed higher resistance to pathogens (Yi-Can Zhang *et al.*, 2017). Tristeza viral disease infected acid lime trees have been observed in some of the orchards of Nellore district and also in few growers' fields from Guntur (Tenali region), where they planted budlings duly adopting closer spacing's of 5m × 5m and 4m × 4m (Mukundalakshmi and Venkataramana, 2016).

Hence, rootstocks are not used for commercial propagation of acid lime. However, during recent periods, acid lime budlings on Rangpur lime rootstock are demanded by the growers with the hope of achieving higher yields, but there is a need to educate the farmers about the advantages of nucellar seedlings over budlings, as budlings are recommended only to address specific abiotic (salinity and drought) and biotic (resistant to diseases canker, phytophthora and tristeza) stresses. The comparison based on research findings at

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Table 1. Comparison of budlings vs seedlings in acid lime.

Characteristic	Budlings	Seedlings	Reference
Precocity	Early (3 years) 2-3 years after planting	Late (4-5 years) 4 years after planting	Naik *et al.,* 1949 Bhujanga Rao Rangacharlu, 1954 Rangacharlu and Rao, 1959
Plant growth	Dwarf and canopy spread is more less	Upright and greater canopy more	
Thorns	Higher yields: 1568kg/tree (25 years)	Poor yielders but would tend to equalise in the long run. 1612 kg/tree (25 years)	
Cumulative mean fruit yield/tree			
Fruit weight (grams)	35-38	45	
Juice (%)	45-48%	48	
Ascorbic acid (mg/100g of juice)	25-26	26	
Gummosis disease incidence	Highly susceptible	Tolerance	
Tristeza virus decline	Susceptible	Resistant	Rajput and Sreeharibabu, 1986
Life span (years)	10-12	20	Naik *et al.,* 1949 Bhujanga Rao Rangacharlu, 1954 Rangacharlu and Rao, 1959

Ananthrajupet and Tirupati, Andhra Pradesh clearly gives an idea of seedlings advantage over budlings in acid lime (Table 1).

The present-day acid lime growers have apprehension that budlings produce comparatively higher yield than seedlings in acid lime which is not true in research findings where Rao *et al.* (1971) noticed that there was no significant difference in cumulative mean fruit yield between budlings grafted onto different rootstocks and seedlings and also there could be no difference with regard to fruit weight between budlings and seedlings. The differences between different rootstocks in grades of fruits, saleable fruits and physico-chemical constituents were not appreciable as seen from the data generated at Fruit Research Station, Anantharajupet and for example, the juice content (%) was 46.84 in Jambheri, 46.98 in Gajanimma and 46.19 in acid lime rootstock.

In our regular surveys, it was observed that acidlime budlings are early prone to decline and mortality than seedlings and studies on susceptibility to decline proved that the tree mortalities were noticed from the twelfth year on Jambheri, thirteenth year on Gajanimma, sixteenth year on acid lime and eighteenth year in respect of seedlings (Rao *et al.* 1971). Similarly, farmers perception has also been taken into consideration where the budded plants are more prone to diseases (gummosis) there by decreasing the tree life and increasing the cost of cultivation for replanting of the orchard. Hence the presence of high polyembryony has enabled the commercial acid lime cultivation on its own roots.

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Correlation coefficient studies in pole type lablab bean (*Lablab purpureus*)

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Dolichos bean is a perennial herbaceous plant often grown as an annual mainly grown for its young pod and green immature seeds for vegetable purpose. Dolichos bean can grown in different agro climatic conditions due to its wide adaptability therefore, it is necessary to select variety having desired pod quality with high-yielding potential. It is however, desirable to know the degree to which different component characters are correlated (Sharma *et al.* 2014). The study was, therefore undertaken to determine correlation coefficients both at genotypic and phenotypic levels and the genotypic and phenotypic correlations were computed by using the formula given by Panse and Sukhatme (1967).

An overall observation of correlation coefficient analysis revealed that number of clusters / plant and number of pods / plant expressed a highly significant positive correlation with pod yield / plant at both phenotypic and genotypic levels. Pod length also showed significant positive correlation with pod yield / plant at phenotypic and genotypic levels.

The experiment was conducted in RBD (Randomized Block Design) with three replications having 25 local pole type dolichos bean genotypes which were locally collected across the Karnataka during 2019-2020.

As correlation coefficients are the index of association between two variables; these have been worked out in all possible combinations at genotypic (G) and phenotypic (P) levels. The correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components. The correlation analysis revealed that pod yield per plant expressed a highly significant positive correlation with number of pods / plant (r = 0. 449, r = 0. 438) and number of clusters / plant (r = 0. 477, r = 0.467) at both genotypic and phenotypic levels. Pod length (r = 0. 285, r = 0.280) and pod width (r = 0. 187, r = 0.176) also showed significant positive correlation with pod yield / plant at genotypic and phenotypic levels. Average pod weight (r = 0.308) showed significant positive correlation with pod yield / plant at genotypic levels. Hence, direct selection for these traits may lead to the development of high green pod yielding in dolichos genotypes.

Correlation coefficient analysis revealed that number of clusters / plant and number of pods / plant expressed a highly significant positive correlation with pod yield / plant at both phenotypic and genotypic levels.

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Stevia MDST-16 : a boon to diabetics

Dr Rajaram Tripathi, a progressive farmer, running the Maa Dhanteshwari Herbal Research Centre at Konda Gaon in Chhattisgarh, India, has developed a new variety of stevia, with the technical support of scientists of the Indian Himalayan Bioresource Technology, Palampur, Himachal Pradesh and Indira Gandhi Krishi Vishvavidyalay, Raipur. Christined, as MDST-16. New variety is sweeter 30 times more than sugar and has zero calorific value and very sweet in taste. The MDST-16 is easier in cultivation, saving 90 per cent water than sugarcane crop. The adoption and cultivation of MDST-16 has become the game-changer for the area. The farmers are earning a lot of income by its cultivation. The powder of its leaves is being commercialised by packing.

For further interaction, please call to:
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New vegetable varieties from IARI, New Delhi

Tomato Pusa Protected 1

This is the first indigenous open- pollinated variety from IARI for polyhouse cultivation. It is suitable for naturally-ventilated and low-cost polyhouse / protected cultivation. The fruits are round, deep red in colour with average fruit weight of 80-85g. The ripe red fruits have TSS 5.6°brix and lycopene content 8.0mg / 100g. It gives an average yield of 12-14 kg / m^2 in 9-10 month crop duration. Fruits are suitable for distant transportation. Its yield potential is 120-140 q / 1000 m^2.

It is recommended for growing in National Capital Region of Delhi and North Indian plains under naturally-ventilated and environmentally controlled greenhouse conditions from Mid-August to Mid-May.

Pusa Golden Cherry Tomato 2

It is promising yellow cherry tomato for protected cultivation. It has 9-10 average flower truss per plant. The average fruit weight is 7-8 g with average fruit yield of 3-4.5 kg / plant with yield potential of 9-11 t / 1000 m^2. The fruits are ready for first picking in 75-80 days and crop lasts for 9-10 months. The fruits contain 13.02 mg / 100 g carotene, 18.3 mg / 100g ascorbic acid, 0.33% acidity and TSS 9°brix.

Pakchoi : Pusa Pakchoi 1

This is first indigenous pakchoi variety developed for North Indian Plains. Its plant becomes ready for harvesting 45-50 days after transplanting. It has attractive light green color and average weight of 500-650 g, with tender flesh. It is a winter season crop which gives average yield of 500-550 q / ha.

It is recommended for growing in winter season in National Capital Region of Delhi, North and Central India under irrigated conditions in normal soil.

For further information, please write to :
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