

Nutrient Management in Onion and Garlic

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Abstract Onion and garlic are important bulbous crops grown worldwide and in India as vegetable and spice crops. Productivity of these crops are reached plateau over last decade in India. Productivity could be increased by judicious use all available resources and proper nutrient management practices. These crops remove 85-90% major nutrients up to 60-75 days after planting. However, these crops remove micronutrients till maturity. Therefore, required major nutrients should be applied as per crop requirement at time and in right place through right source. Season long supply of micronutrients are essential for achieving higher production. Continuous application of inorganic fertilizers could deteriorate soil health and affect onion and garlic productivity. Organic manures have both major and micronutrients, but it is very difficult to synchronize the nutrient release and crop nutrient demand. Hence, balanced application of inorganic fertilizers, organic manures and biofertilizers are essential for achieving higher productivity and for sustaining soil health.

Keywords Productivity, Nutrient uptake, Organic manures, Inorganic fertilizers, Biofertilizers, Balanced application

Introduction

Onion and garlic are important bulbous crops grown worldwide as vegetable and spice crops. India rank second in both area and production of onion and garlic. However, the productivity remained static over last decade. One of the reasons for this low productivity could be unbalanced fertilizer use. The productivity can be increased with balanced application of plant nutrients through different sources. Onion and garlic are heavy feeders, extract nutrients from the soil to meet the crop requirement which results in depletion of essential nutrients from the soil native reserves. Application of chemical fertilizers has played a crucial role in replenishment of nutrients removed by crops and crop yield increase. However, continuous application of chemical fertilizers alone over the years resulted in loss of soil organic carbon and deteriorated soil environment.

Soil organic matter is a key component as it influences soil biological, physical and chemical properties that define soil

quality (Doran and Parkin 1994). Further, the poor nutrient management practices followed in the past to the raise crops have resulted in loss of nutrients through volatilization, leaching, de-nitrification and run off and causing soil and water pollution. Application of organic manures alone will improve the soil health whereas, achieving higher bulb yield with application of organic manures alone as sources of plant nutrients is not possible. The largest challenge at present is to increase the productivity of these crops with judicious use of available resources, while sustaining soil health. The main aim of the nutrient management is to increase onion and garlic production through judicious use of fertilizers and manures and maintain soil health. In this article, we tried to cover fertility status of Indian soils, nutrient requirement of these crops and management.

Nutrient Requirement

Nutrient uptake of onion and garlic crop is presented in table 1. Onion crop require about 2.10 – 2.16 kg N, 0.70-0.80 kg P₂O₅, 2.00-2.25 kg K₂O and 0.25-0.30 kg S for yielding a ton of onion bulbs (Thangasamy 2016). Similar studies by Dogliotti (2003) reported that onion-crop removed 1.92 kg N, 0.30 kg P and 1.30 kg K, and Zhao et al. (2009) found that the crop needed 2.93, 1.16 and 2.69 kg of N, P₂O₅ and K₂O,

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respectively. Similarly, Garlic crop removed 9.49 kg N, 1.21 kg P and 3.80 kg K to produce one tone of garlic bulbs. These all studies indicated that nutrient requirement were more or less similar to produce a ton of onion and garlic bulbs at varied locations and also for different varieties or ecotypes like long-day or short-day. The dry matter accumulation was very slow at the initial establishment stage, up to 20 days after transplanting (DAT), and was at a faster rate after 20 DAT. Daily dry matter accumulation rate reached a maximum after 55-60 DAT (Figure 1). Total nitrogen and potassium uptake rate increased rapidly from 15 DAT and reached maximum at 45 DAT (Figure 2 and 3). Peak N and K uptake rate was recorded during 33-40 DAT. The uptake rate decreased after 45 DAT and reached zero at 90 DAT. However, nutrient uptake rate of nitrogen and potassium at 90 DAT was 0.12 and 0.66 kg/ha/day, respectively. It indicated that nutrients accumulated in leaves were remobilized and translocated from leaves to bulbs at maturity stage (Thangasamy 2016). The rapid uptake of these nutrients occurred during vegetative growth. Total phosphorus and sulphur uptake rate occurred at a faster rate during 30-60 DAT (Figure 4 and 5). Peak uptake rate of these nutrients were observed during 45-50 DAT. The uptake pattern of these nutrients showed that these nutrients are

required during bulb initiation and bulb development stages. Plants remove micronutrients up to maturity. Hence, season long supply of micronutrients is essential for achieving higher bulb yield (Thangasamy 2016). Garlic crop also followed similar nutrient uptake pattern (Thangasamy and Chavan 2017).

Similar P uptake pattern was observed in long day onion with 4% of total uptake during seedling stage and 91% of during rapid growth stage (Zhao et al. 2009). The uptake rate of these two nutrients was stabilized 90 DAT. Onion crops removed 11-12% of total P and S during 75-120 DAT and less than 10% for N and K. Like N and K, P and S accumulated in leaves were also remobilized and translocated to bulbs at maturity stage. Similar results were recorded in intransgenic maize (Bender et al. 2013) and soybean (Bender et al. 2015). Hence, soil application of required NPKS should be made before 60 DAT and application after 60 days is seldom effective in increasing bulb yield. Both in onion and garlic, about 80-90% of the nutrients are removed by bulbs and the nutrients accumulated in bulbs may be replaced through external sources of plant nutrients. The nutrients accumulated in leaves may be recycled through reincorporation in to the same field.

Table 1 Nutrient uptake/dry matter accumulation by onion cv. Bhima Kiran to produce 45 t onion bulbs/ha and garlic cv. G 41 to produce 6-8 t/ha

Nutrient/dry matter	Onion			Harvest Index	Garlic			Harvest Index
	Nutrient uptake/dry matter accumulation				Nutrient uptake/dry matter accumulation			
	Leaves	Bulbs	Total		Leaves	Bulbs	Total	
Dry matter yield (kg/ha)	708.9	3604.2	4313.1	83.6	1144.0	4231.0	5375.0	78.7
Nitrogen (kg/ha)	6.1	74.4	80.5	92.5	14.5	103.4	117.9	87.7
Phosphorus (kg/ha)	0.5	15.3	15.8	97.1	1.1	13.2	14.3	92.4
Potassium (kg/ha)	15.6	52.8	68.4	77.2	26.7	48.3	75.0	64.4
Sulphur (kg/ha)	1.7	13.1	14.8	88.6	3.5	34.4	38.0	90.7
Iron (g/ha)	543.0	592.0	1135.0	52.2	2014.9	3791.2	5806.1	65.3
Zinc (g/ha)	17.2	90.5	107.7	84.1	23.7	133.0	156.7	84.9
Manganese (g/ha)	42.9	65.3	108.2	60.4	54.6	124.0	178.6	69.4
Copper (g/ha)	2.7	10.8	13.5	79.9	5.3	13.0	18.2	71.1
Boron (g/ha)	407.0	1273.0	1680.0	75.8	-	-	-	-

Source: Ganeshamurthy et al. (2017)



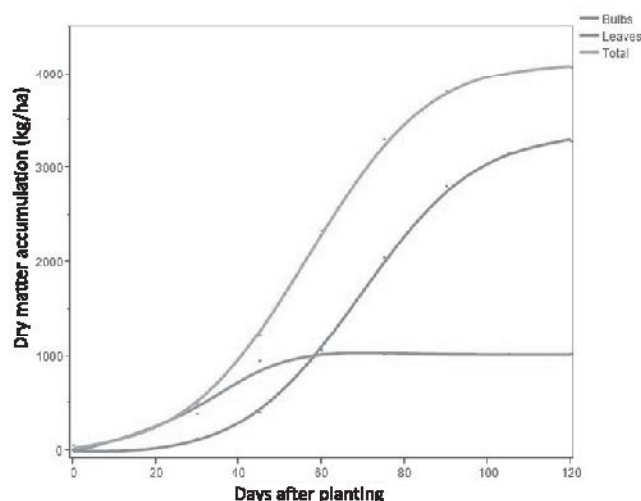


Fig. 1 Dry matter accumulation in onion bulb crop during plant growth period

Soil Fertility Status of Onion and Garlic Growing Areas

Being a tropical country, most of the Indian soils are deficient in available nitrogen and low in soil organic carbon level. Out of 133 districts, forty-three districts are deficient in available phosphorus and 40% of districts deficient in sulphur. Almost all the soils of onion and growing areas are having medium to high in potassium, calcium and magnesium content (Ganeshamurthy et al. 2017). Two-hundred and fifty soil samples were collected from 15 villages of Pune district and analysed for soil fertility status. The soil analysis showed that about 25–30% soil samples were high, about 45–50% medium in phosphorus, all the soils were low in N and soil organic carbon and high in potassium. The high phosphorus content in soil samples were due to excess use phosphoric fertilizers to onion and garlic. The farmers of these areas were mainly applied DAP and to some extent potassic fertilizers and urea. Excess application of DAP resulted in build up of soil available P. Although K is present in medium to high range, application of required nutrients is vital to maintain equilibrium and to sustain soil health. Crop production without potassium application over the years may lead to unbalance in soil nutrients and reduces yield. About 44% of total onion and garlic growing districts in India are deficient in zinc deficiency and 15% is deficient in iron and 13% in boron deficiency (Ganeshamurthy et al. 2017). Onions and garlic grown in highly acidic and organic matter rich soils or on light textured alkaline soils generally show deficiency of

boron. Almost all onion and garlic growing soils of India are sufficient in manganese and copper. Application of micronutrient inevitable in areas showing micronutrient deficiency.

Nutrient Management

Unbalanced Use of Inorganic Fertilizers

Fertilizer consumption in India is unbalanced since the beginning, tilted more towards N followed by P. Even today, the situation is grim as far as fertilizer application by farmers is concerned. In many areas the unbalanced fertilization is the root cause of poor crop yields and soil fertility status (Subbarao and Sammi Reddy 2006). However, onion and garlic farmers are totally avoiding urea because excess application of urea increases neck thickness and double bulbs (Palaniappan and Thangasamy 2015). Inadequate supply of nitrogen, potassium and sulphur cause depletion of soil native reserves while excess application of phosphoric fertilizers every season has resulted in build up which affects availability of other mineral nutrients or lost through different means. Prasad and Sinha (1981) observed that continuous application of 150% NPK application resulted in increase of 59.0 and 278.0 kg/ha of phosphorus and potassium, respectively after eight years in long term manure and fertilizer experiment. Available phosphorus content in soil changed from low status in the early 2000 (12 kg/ha) to medium (20–24 kg/ha) in 2011 at DOGR farm, Rajgurunagar. This increase in available P was due to continuous application of P_2O_5 @ 50 kg ha⁻¹ to onion and garlic crops every season (Thangasamy et al. 2010). The potassium balance in soil consistently remained negative and K supply through external sources was less than the crop removal in many places of the country. Negative balance has resulted in serious soil K depletion, which could be limiting the crop yield increase (World Bank Report 2007). Soils subjected to high cropping intensity and thus high K removals suffer a considerable reduction in non-exchangeable content compared to soils with a low cropping intensity (Mingfang et al. 1999).

Sulphur plays important role in onions and other cultivated alliums because it directly influences their unique flavour and pungency. Sulphur is a primary element in many compounds that produce a specific flavour profile to a specific species of Alliums. These compounds are essential in pungency development in Alliums, especially onion and garlic. Qureshi and Lawande (2006) revealed that onion yield

were increased with increasing sulphur nutrition level up to 75 kg ha⁻¹ in low sulphur soils (<10 ppm S) while no increase was recorded in soils having high sulphur levels (Yoo et al. 2006). Further, application 20 kg S ha⁻¹ was found to be sufficient for optimum onion bulb production in soils having sufficient sulphur level (Thangasamy et al. 2013). In a study, the importance of interaction of selenium and sulphur on onion quality parameters was noticed. Application of selenium as sodium selenite at 20 kg ha⁻¹ significantly decreased the S content of onion bulbs and the pungency of

bulbs. Foliar application of Se of more than 1.0 ppm concentration to onion seedlings up to 60 days after transplanting decreased the total S content in bulbs, and furthermore the quality parameters, namely pungency and quercetin, in bulbs were affected (Qureshi et al. 2012). Besides primary and secondary nutrients, the increasing deficiency of micronutrients is also becoming a cause of concern. Micronutrient deficiency can be corrected by regular application of organic manures to the soil (Qureshi et al. 2011).

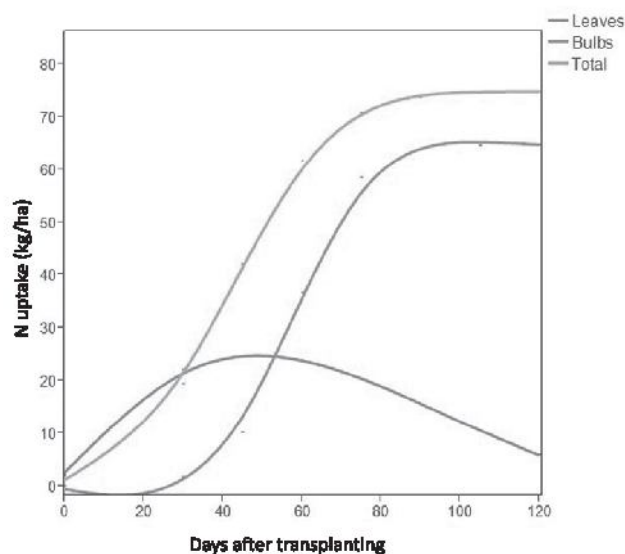


Fig. 2 N uptake pattern of onion bulb crop during crop growth period

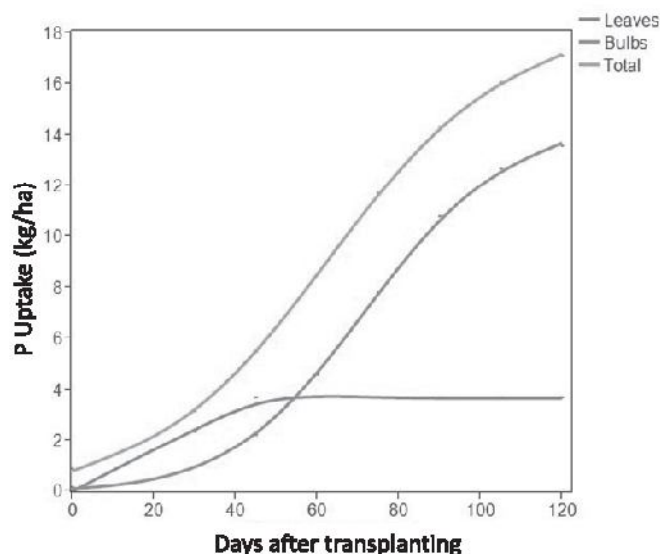


Fig. 3 P uptake pattern of onion bulb crop during crop growth period

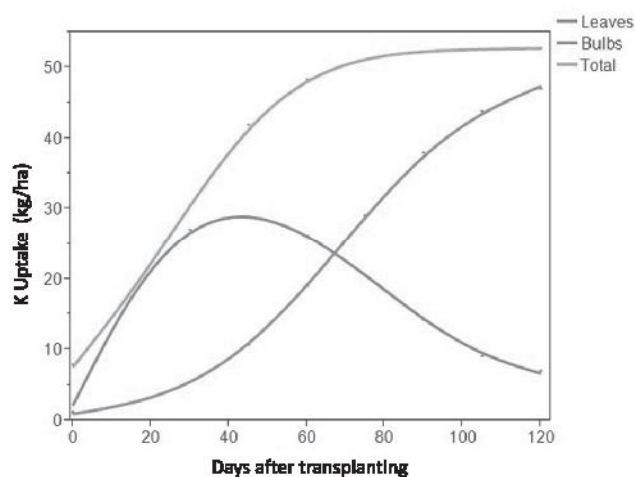


Fig. 4 K uptake pattern of onion bulb crop during crop growth period

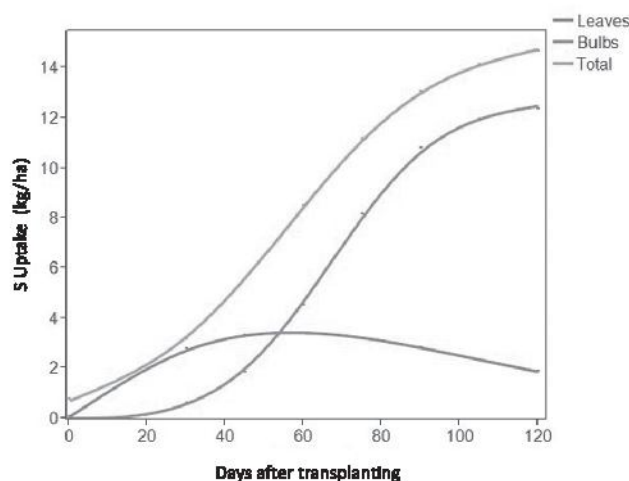


Fig. 5 S uptake pattern of onion bulb crop during crop growth period

Source: Thangasamy (2016)

Organic Farming

The benefits of long-term application of organic manures have long been recognized, and confirmed by long-term experiments. Addition of organic manures in the fertilizer programme is inevitable because it is a source of secondary and micronutrients, improves soil organic carbon level, soil physical environment and soil microbial activity. Addition of organic manures over the years continuously enhanced the soil physical properties such as soil organic matter content, hydraulic conductivity, porosity and aggregate stability, lowered bulk density and increased soil biological activity than soils only receiving inorganic fertilizers (Edmeades 2003 and Diacono and Montemurro 2010). Organic manure is a reservoir for essential plant nutrients and contains sufficient quantity of micronutrients (Table 4). Continuous addition of organic manures, supply micronutrients to the crop as it decompose over time. Soils that receive regular additions of organic residues such as manures rarely show micronutrient deficiencies. On decomposition of organic manure, it releases organic acids which solubilises soil native or applied micronutrients and makes it available to plants. Inoculation of plant-growth-promoting fungus *Trichoderma harzianum* solubilise Fe_2O_3 , MnO_2 , metallic zinc, and rock phosphate in a liquid sucrose-yeast extract

medium through chelation and reduction (Altomare et al. 1999). Liu et al. (2000) reported that inoculation of mycorrhiza into low micronutrient soils increased Zn, Mn and Cu concentration in plants as compared non-inoculated soils.

However, organic farming reduced onion bulb yield by 33-42% over conventional farming after six years of continuous cultivation compared to conventional farming (Thangasamy et al. 2018). N, P, K and S uptake increased by 11.9-23.4, 21.7-32.5, 22.7-49.1 and 62.5-66.5%, respectively, over FYM, PM and VC treatments. Organic farming increased TSS, total phenol, quercetin 3 glycosides, flavonoid and ascorbic acid content of onion bulbs over conventional system. Among the organic manures, vermi-compost application had higher total phenol (21.5%), flavonoid (79.3%) and ascorbic acid content (22.5%) over conventional method. Organic farming significantly increased soil organic carbon content (11-16%) and bacterial population increased by 1.7-2.6 times, fungal and Actinomycetes population by 2.5-4.4 and 4.1-7.5 times, respectively over conventional method. The economic return received from organic farming was significantly higher (37.9-49.3%) over conventional system due to the higher market price for organic produce.

Table 2 Micronutrient content in different organic manures

Organic manure	Micronutrient content (mg/kg)					
	Fe	Zn	Mn	Cu	B	Mo
FYM	1788	34	137	2.5	4.5	2.1
Poultry manure	1400	90	210	7.1	5.0	3.1
Goat/sheep manure	6500	2570	150	61.0	4600.0	3.5
Pig manure	1200	50	70	8.9	3.5	1.4
City waste	7000	400	560	150.0	15.0	9.0
Rural compost	3600	85	200	14.0	10.0	2.0

Source: Sahu and Samant (2006)

According to Sankar et al. (2009), higher marketable bulb yield in white onion along with better post-harvest storage-life was obtained with combined application of FYM (FYM 50% as equivalent to recommended dose of NPK) + poultry manure (50% as equivalent to recommended dose of NPK) + bio-fertilizers + foliar application 3% Panchakavya. Lee (2010) reported that application of liquid organic fertilizer over the mulch was effective in increasing the onion bulb yield and no significant yield difference was found between

chemical fertilization and organic fertilization with mulch. Selvaraj et al. (1993) observed better garlic yield supplied with 25 tonnes of FYM ha^{-1} . None of the organic fertilizer products evaluated significantly increased onion yield or quality compared to the inorganic fertilizer (Feibert et al. 2003). In general, organic farming reduced 25-40% bulb yield both in onion and garlic. Hence, we need to have alternate system involving both inorganic fertilizers and organic manures for increasing bulb production and to maintain soil health.

Integrated Plant Nutrient System

Integrated plant nutrient system (IPNS) system is an age-old concept. Its importance was not realized earlier as nutrient removal by the crops was very low due to subsistence farming. At present, IPNS system has a great significance because of intensive farming. Its need in modern agriculture has arisen due to high price of chemical fertilizers, unbalance in NPK use, and deterioration of soil health, consumption of non-renewable energy sources by inorganic fertilizers, organic materials as a source of secondary and micronutrients (Mahajan et al. 2008). Inclusion of organic manures in IPNS can reduce costly inorganic fertilizer requirement and save energy by reducing the fertilizer production. Several studies had been conducted to evaluate the effect of combined application of inorganic and organic manures on yield and yield parameters at different locations.

Vinay Singh and Manoj Pandey (2006) reported that application of 75% NPK along with 10 t FYM/ha and *Azotobacter* produced yield at par with 100% recommended dose of fertilizers which was significantly higher over the control without fertilizer application in sandy loam soils of Bichpuri, Uttar Pradesh. Similarly, combined application of 75% NPK, 10 t FYM or 5 t Poultry manure or 5 t vermicompost/ha and *Azotobacter* produced yield at par with 100 % RDF + 20 t FYM/ha and 100 % RDF at Rajgurunagar (Thangasamy and Lawande 2015). Similar results were recorded at Srinagar, Udaipur, Dharwad, Samastipur, Hisar, and Jabalpur. However, mean bulb yield recorded varied significantly between different locations (AINRPOG Annual report 2011). The higher yields obtained with organic manure + NPK treatment were possibly caused by other benefits of organic manure besides N, P and K supply, such as improvements in microbial activities, better supply of macro and micronutrients such as Zn, Cu, Mn, Fe and B, which are not supplied by inorganic fertilizers. Li et al. (2007) reported that integrated use of inorganic fertilizers and organic manure significantly increased the DTPA-extractable concentrations of Zn, Fe and Mn compared to the control after 16 years of cultivation. Application of dairy manures and NPK fertilizers over 18 years has increased DTPA extractable Fe and maintained DTPA extractable Mn, Zn and Cu as compared to the initial values (Zhang et al. 2015). Balanced application of fertilizers and manures along with bio-fertilizers will improve bulb yield and nutrient use efficiency. However, the release of nutrients to plants from these sources should coincide with critical stages of nutrient requirement for increasing bulb yield and nutrient use efficiency.

Foliar Application of Micronutrients

Foliar application of micronutrients during crop growth was successfully used for correcting their deficits and improving the mineral status of plants as well as increasing the crop yield and quality (Kolota and Osinska 2001). Application of recommended organic manures, inorganic fertilizers and foliar application of Fe or Zn at 60 and 70 days after transplanting significantly increases plant vegetative growth (Singh and Tiwari 1995) as well as bulb yield and quality of onion (Singh and Tiwari 1996). Integrated use of FYM, inorganic fertilizers and foliar feeding of Zn @ 4 mg/l significantly improved vegetative growth parameters, total yield and quality contents in bulb as compared to control (Ballabh et al. 2013). Integrated use of vermicom post and foliar application of micronutrient mixture increased marketable bulb yield by 16.9% followed by foliar application of zinc sulphate @ 0.5% (10.5%), soil application of zinc sulphate @ 10 kg/ha (10.3%), foliar application of boric acid @ 0.25% (8.3%) over control. Storage data showed that the soil application of zinc sulphate and boric acid @10 kg/ha reduced storage losses by 11.8 and 24.1%, respectively over control after 6 months of storage. The improved storage quality is due to improved plant health and quality. The results of in-vitro study showed that both boric acid (1.0%) and zinc sulphate (0.5 and 1.0%) provided 100% mycelial inhibition, whereas, boric acid @0.25% showed 41% and 43% mycelial inhibition of *Stemphylium vesicarium* and *Colletotrichum gloeosporoides*, respectively. At 0.5% concentration, boric acid reduced 63% of *Stemphylium vesicarium* and 51% *Colletotrichum gloeosporoides* mycelial growth (Thangasamy et al. 2016). Foliar application of boric acid and ZnSO₄ not only increased bulb yield, but also reduced *Stemphylium* incidence and improved keeping quality of onion and garlic. Micronutrients can also be applied through seed treatments for increasing bulb yield of these crops. Seed treatment is a better option from an economical perspective as less micronutrient is needed, it is easy to apply and seedling growth is improved (Singh et al. 2003).

Soil Health

The activity of soil organisms is very important for ensuring sufficient nutrient supply to the plant. If microorganisms find suitable conditions for their growth, they can be very efficient in dissolving nutrients and making them available to plants. Moreover, an increase in soil microbial-biomass C

and nitrogen is obvious in soils receiving combined application of organic manures and chemical fertilizers compared to soils receiving chemical fertilizers only. The use of organic fertilizer together with chemical fertilizers, compared to the addition of organic fertilizers alone, has a higher positive effect on microbial biomass and hence soil health (Dutta et al. 2003). An application of NPK along with FYM showed a significant increase in the status of available nutrients over the treatments received either inorganic fertilizers or FYM (Vinay Singh and Manoj Pandey 2006). Combined application of organic manures and inorganic fertilizers to onion and garlic crops improved the soil available nutrients and soil enzyme activities at Rajgurunagar as compared to the initial values (NRCOG Annual report 2007).

At Long-term experiment conducted in India, Hatiet al. (2007) found that the combined application of NPK and FYM not only produced significantly higher soybean and wheat yields than NPK treatment, but also increased SOC by 56.3% compared with the initial SOC value at the beginning of the experiment. The treatment increased soil electrical conductivity, SOC content, aggregation, water retention, micro-porosity and available water holding capacity, but decreased soil bulk density over all other treatments. The results of INPS conducted at various location India and worldwide showed that integrated use of inorganic and organic sources increased bulb yield, quality, soil organic carbon and improved soil health. However, the efficiency of applied nutrient is very low which needs to be increased without affecting the bulb yield. Hence, the current requirement is to increase the efficiency of applied nutrients. This could be achieved through balanced application of plant nutrients as per crop requirement through organic and inorganic sources of plant nutrients at right time and in right quantity. The nutrient use efficiency can be increased through inoculation of plant growth promoting microorganism and mycorrhizal fungi.

There are several challenges in the use of organic amendments in agriculture. Crop residues are being used as animal feed and for fuel purpose in rural India which affects recycling of crop wastes. To avoid these problems, alternate sources such as green leaf manures, residue recycling, and compost developed from city wastes etc. may be used in IPNS. Another challenge is the difficulty of accurately predicting nutrient mineralization from different types of manures in different cropping environments, leading to either over- or under-application of inorganic fertilizers (Zhao et al. 2010). If the organic manures are added as such

in the field without decomposition, immobilization of nutrients will occur which may affect the crop yields severely. Hence it is vital to use well decomposed organic manures to avoid immobilization of plant nutrients.

Conclusions

Onion and garlic are important bulbous crops grown worldwide. Though, India ranks second in area and production, the productivity of these crops are very low which can be increased through improved agronomic practices and balanced use of plant nutrients. Continuous application of inorganic fertilizers deteriorated soil health and environment, but, organic farming reduced about 25-40% bulb yield of onion and garlic over conventional method. Balanced and integrated use of fertilizers and manures increased bulb yield, increased organic carbon level, fertility status and physical properties. However, the use efficiency of applied nutrients is very low and remain major concern. The plant nutrients needs to be applied in an integrated manner through well decomposed organic manures, biofertilizers and inorganic fertilizers as per crop requirement at right time and at right quantity. Inoculation of plant growth promoting microorganisms and nutrient solubilizing bacteria will play a vital role in increasing nutrient use efficiency and bulb yield.

Future Thrusts

- Fertilizer scheduling as per requirement at right time and at right quantity to enhance nutrient use efficiency through drip irrigation system.
- Quantification of nutrient losses by different means to improve nutrient use efficiency
- Improving nutrient use efficiency through inoculation of plant growth promoting microorganisms and mycorrhiza.
- Screening of onion and garlic germplasm for higher nutrient use efficiency/enhancing the nutrient use efficiency of crops through traditional breeding methods or using biotechnological tools.

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