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Integrated Nutrient Management in Onion-A Review

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ABSTRACT

Onion (*Allium cepa* L.) is a bulbous vegetable crop and cultivated in many parts of the world. Onion is majorly used in our daily diet for its nutritional value. In onions, sulfur-containing compounds and allinase enzymes are responsible for their lachrymatory effect and pungency. Flavanoid compounds in onions like kampeferol and quercitin show anti-inflammatory and antioxidant properties. Globally, India stands second in onion production, book keeping for 10 % of total production from 16 % of total area. As per FAO data (2012), China leads the world in production (20.5 million tonnes), followed by India (13.3 million tonnes). Maharashtra, Madhya Pradesh, Karnataka, Rajasthan, Bihar, Gujarat, Andhra Pradesh, Haryana, West Bengal, Gujarat, and Uttar Pradesh are the top onion-producing states in the country, contributing nearly 90% of the country's overall onion production. Maharashtra stands first in production with 8,854.09 thousand tonnes with 38.09 percent share, followed by Madhya Pradesh (15.92 percent share) and Karnataka (12.85 percent share) (https://agriexchange.apeda.gov.in). Onion is a nutrient-sensitive crop and the nutrient requirement varies with cultivar, location, and season. Fertilizer recommendation for onion crop is 100-150 kg N, 40-80 kg P_2O_5, and 0-125 kg K_2O per hectare (Source: NHB). Many studies have reported that 2.1 kg N, 0.75 kg P_2O_5, 2.2 K_2O, and 0.28 kg S per hectare of nutrients are removed by onion crop to produce a bulb yield of 1 ton (DOGR, 2015). Use of synthetic fertilizers alone causes leaching, increases toxicity, and degrades the soil environment. A Study by Kwaghe *et al*. (2017) have shown that nutrient uptake by the onion crop enhanced to 0.76, 43.82, and 2.42 kg/ha by the combination of both organic and inorganic fertilizers, thereby increasing the crop yield. Therefore, a rising need exists to provide an adequate and balanced nutrient application for attaining good crop yield and quality without affecting soil fertility status. This INM based approach for nutrient management has a positive impact on plant growth, agricultural sustainability, and fertility of soil. Hence to enhance soil fertility and to improve the nutrient uptake, the concept of Integrated Nutrient Management (INM) could be adopted.

Key words: *Onion, INM, Fertilizers, Organic manures, Bio-fertilizers, Micro-nutrients, Nano fertilizers, Bio-stimulants*

Introduction

Fertilizers are a significant source of plant nutrients, and the nutrients could be delivered efficiently by following the appropriate nutrient management practices. Integrated nutrient management involves sustaining soil fertility and nutrient supply at optimal quantity to attain better crop productivity. As stated by Natural Resource Conservation Service, healthy soil is defined ascontinued " capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans ". INM is also referred to as IPNS (Integrated Plant Nutrient System), which aims to maintain soil fertility and increase crop yield by combining the applications of chemical-based fertilizers, industrial wastes, farm waste/ organic wastes, and many more inputs of biological origin. Using chemical fertilizers alone by farmers is costly and may impact soil health and the environment. Hence, nutrient supply through organic means is eco-friendly and enhances plant growth development and yield. INM include biofertilizers, organic sources, legumes, and chemical fertilizers. Combining all these components would achieve a high fertilizer use efficiency.

Nutrient Management

Managing plant nutrient requirements are essential for optimizing crop growth and yield. Mineral uptake in plants hinge on different variables such as crop variety, plant population, crop milieu, method of fertilizer application, soil fertility, and proper fertilizer distribution to the crop through the appropriate irrigation system.

Integrated Nutrient Management

As crop production and yield depend mainly on the fertilizer inputs, it is necessary to look forward to the fertilizer application. Soil health is diminishing due to high tillage practices, overuse of soluble fertilizers, and insufficient organic input sources. INM approaches also seek to improve soil conditions by enhancing farm production and reducing soil degradation by increasing physical, chemical, biological, and hydrological qualities. Some principles of INM include maximizing the use of all possible available sources, increasing the efficiency of inorganic fertilizers usage, and reducing nutrient loss through leaching. According to Nath *et al*. (2011), INM shows better results in improving organic carbon content, soil microbial population, and enzymatic activities in soil. Integrated Soil Crop System Management (ISSM) focuses on redesigning the complete cropping system, including variety of crop, seed sowing, harvesting dates and plant population, to make the most of solar radiation and favorable temperature periods based on local climatic conditions. Studies confirmed that the ISSM approach had increased the efficiency of nutirient usage in many of the cereal crops. It aids in optimizing soil tillage practices, improving soil quality, synchronizing the nutrient demand-supply for the crops from the environment, soil, and fertilizers. They have also resulted in reduced nitrogen losses and greenhouse gas emissions.

Integrated Nutrient Managemnt

Components of INM system

Crop Wastes or Residues

Locally available crop wastes *viz*., plant waste, leftover cattle feed, and residues in harvested fields are collected and dumped in the compost yard for decomposing. The plant waste materials are cut down to reduce the particle size, which favors quick waste decomposition. Compost heaps are regularly monitored by mixing the waste materials turning upside down, which provides better aeration to the compost material. They are watered to maintain the moisture content of the material. By holding 60% of moisture inside the compost material, soil microorganisms get activated and promote the compost material's rapid decomposition.

Legumes

Winter legumes such as pea green manures supplement the crops with a high amount of nitrogen and organic matter by building the soil properties, managing optimum moisture capacity, and improving the crop yield. When incorporated into the soil, leguminous crops are involved in biological nitrogen fixation. Rhizobia bacteria reside in the roots of the legumes. As it multiplies, the root swells and shows pale pink color nodules. This bacteria exists in soil by intaking the soil carbohydrates formed by photosynthetic activity. Rhizobia bacteria release ammonia by consuming nitrogen from air and hydrogen from carbohydrates and supplying them to the crop. When these crop gets decomposed in the soil, residues releases nitrogen slowly and the succeeding crop utilizes it. Studies by Lalia *et al*. (2017) revealed that bean seeds that are inoculated with Rhizobial

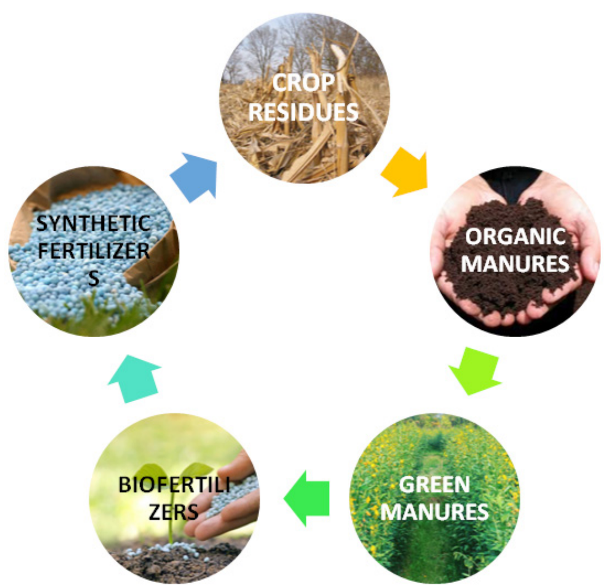

Fig. 1.Key components of INM

strain were grown in the pots, and onion is raised as a subsequent crop. In the experiment, the onion crop is measured for colonization frequency of rhizobacteria, and arbuscle abundance was found out. By measuring the soil respiration intensity, the activity of soil microbes is evaluated. Findings showed that interaction of this mycorrhizal fungi with the onion crop resulted in increased leaf yield and more mycorrhizal structures were observed in these treated experiments.

Organic Manures

Organic manures are incorporated into the land as a cover crop, green manure, crop residue, organic mulche, compost, etc..Organic manure application in soil upshots in organic matter, physical, chemical and biological properties. Crop rotation with certain green manure crops such as alfalfa, vetch, beans, peas, sunhemp, clover and some grass types like ryegrass, buckwheat, rapeseed show long term benefits in soil quality improvement and plant growth development. They also aid in high carbon-nitrogen ratio, soil respiration, and soil microbial activity. Other organic manures may include poultry manure, sheep and goat manure, oil cakes, animal-based concentrated organic manures like horn and hoof meal, crushed bone meal, and raw bone meal. Decomposed plant wastes, cowdung and urine waste, leftover cattle feed, or fodder wastes are considered farmyard manures. These locally available wastes are collected and made to decompose by dumping them in a trench. After decomposition, they are converted into manures which are applied in the field to crops such as onion, tomato, potato, and root crops which respond well to farmyard manure. Maheswarappa *et al*. (1999) have shown that the vermicompost and FYM application resulted in less bulk density, enhanced soil organic carbon, porosity, and water holding capacity when compared to the NPK fertilized field soil. Yassen *et al.* (2009) obtained better results with increased essential oil content and vegetative growth of the onion plant, when supplied with farmyard manure and poultry manure. Studies of Rao *et al*. (2010) opined that the application of vermicompost in onion had resulted in enhanced plant height, leaf length, and leaf size compared to control treatment. Murad *et al*. (2018) pointed out that a local cultivar of onion namely Parachinar responded well to the poultry manure @ 10t/ha with better bulb yield.

Chemical Fertilizers

The introduction of chemical inorganic fertilizers in modern agriculture led to an upsurge in crop yield and crop varieties developed against biotic and abiotic factors. Inorganic fertilizers tremendously contributed to increasing crop production and soil productivity. Chemical fertilizers provide required plant nutrients and immediately boost the crop yield twice. Usage of chemical fertilizers alone causes soil pollution and thus reduction of soil fertility is witnessed. But the amalgamation of organic and inorganic fertilizers resulted in enhanced crop productivity and yield. These mineral fertilizers sustain the crop yield by restoring the depleted soil and replenishing the nutrients removed during harvest. Inorganic fertilizers commonly used are urea, diammonium phosphate, monoammonium phosphate, anhydrous ammonia, ammonium sulfate, and potassium chloride.

Biofertilizers

Biofertilizers are otherwise called microbial inoculants would replace the plenty of chemical fertilizers usage, increase the farm productivity, activate the soil microbial consortia, and stimulate the overall plant growth parameters. These microbial inoculants are a source of plant nutrients that can be either applied in soil or treated to seeds that aid in providing certain growth-promoting substances for plants. These microorganisms are bacteria, blue-green algae, or fungi. The major classification of biofertilizers includes nitrogen-fixing bacteria, potassium solubilizing bacteria, phosphorus solubilizing bacteria, compost enhancers, and plant growth-promoting rhizobacteria. Nitrogen-fixing bacteria *viz*., *Rhizobium*, *Azotobacter*, and *Azospirillum* enhance soil fertility as well as crop yield.These biofertilizers are applied by three common methods such as seed treatment, soil application, and seedling root dip treatment. Ryu *et al*. (2006) reported that pink-pigmented facultative methylotrophic bacteria (PPFMs) belong to *Methylobacterium*. These bacterial strains are inoculated in tomato and red pepper, they have shown high root length and more plant growth-promoting hormones accumulation in the seedlings. *Trichoderma harzianum* composted kitchen wastes combined with 50% NPK application in tomato plants had recorded increased total soluble solids, sugars, abscisic acid, â-carotene, and lycopene (Molla, 2012). As per the experiments carried out at the Directorate of Onion and Garlic Research (DOGR), Rajagurunagar, Maharashtra, application of azospirillums well as phosphorus solubilizing bacteria @5kg/ha is suggested for onion either as a seed treatment or soil application.

Integrated Nutrient Management Approaches in Onion

50% suggested NPK fertilizer dose (suggested dose of NPK is 100 kg N, 50 kgP_2O_5 and 100 kg MOP)+ Vermicompost 2.5 t/ha increased morphological parameters include the number of leaves, the thickness of scale, plant height, equatorial diameter of the bulb, bulb yield, and increased TSS, Vitamin C and Allyl propyl disulfide content in bulbs Krishnaprabhu *et al*. (2020).

Azospirillum (500g/ha) as a seedling dip for an hour before transplanting+100% suggested dose of NPK fertilizers (Full dose of 50 kg P_2O_5/ha and 50 kg K_2O/ha applied during the time of transplanting anda full dose of nitrogen (100kg/ha) is applied in two split doses i.e., 50% as basal and 50% was applied 30 days after transplanting boosted the vegetative as well as yield parameters with high TSS, ascorbic acid content. Talwar Dilpreet *et al*. (2017) 75% of suggested dose of NPK (suggested dose of Nitrogen, Phosphorus, Potassium and Sulphur for onion crop is 100:50:100:60 kg/ha)+ 5t/ha poultry manure and Phosphorous solubilizing bacteria and *Azospirillum* inoculation improved the nutrient availability and increased the photosynthesis rate, thereby increasing the quality parameters (nitrogen, phosphorus, potassium, sulfur, soluble solids, and allyl propyl disulfide content in the bulb) and yield attributes (Mahala *et al*., 2018)

1/3rd of recommended nitrogen through farmyard manure + vermicompost + neem cake + biofertilizer containing nitrogen and phosphorous carriers. Better onion bulb yield and high production efficiency (Narkhede *et al*. (2017)

Complete dose of NPK fertilizers (125, 32.7 and 50 kg/ha) + vermicompost @ 25 t/ha onion production and good soil fertility management under the subtropical zone of Jammu (Gupta *et al*., 2019)

Grass biochar (0.5 kg/m^2) combined with inorganic fertilizer (150kg/ha urea and 100 kg/ha Di Ammonium Phosphate appliedas soil application) increased soil nitrogen accumulation, improved soil properties, and high marketable bulb yield Aneseyee and Tekilil Wolde (2021).

Vermicompost 5t/ha + 50% of the suggestedlevel of inorganic nitrogen (34.5 kg N/ha) enhanced growth and yield attributes of onion (Yohannes Gebremichae *et al*., 2017).

Full dose of inorganic fertlizers (150 kg Nitrogen /ha + 100 kg Phosphorus/ha+ 50 kg potassium/ha) + 6 kg Zn/ha + 20 kg S/ha +10 tonnes of FYM enhanced the Sulphur availability in soil due to the high sulphur supplying capacity of FYM. Thereby increasing the overall crop production and yield (Verma *et al*., (2014).

Fertilizer Schedule for *Kharif* and *Rabi* onion

The amount of nutrients removed by onion crop is mainly determined by bulb output, variety, fertilizer application rate, soil quality, and season. As per the experimental studies conducted in the Directorate of Onion and Garlic Research(DOGR), Rajaguru Nagar, Maharashtra, it has been proven that 90-95 kg of Nirogen, 30-35 kg of Phosphorus and 50-55 kg of potassium are removed by onion crop to get a yield of 40t/ha. Hence to balance the plant nutrient requirements, DOGR recommends applying fertilizers and organic manures as presented in Table 2, and 3.

Thirty three Sixty six per cent of the required N and the full doses of phosphorous and potassium are applied at planting, with the remaining Sixty six per cent of the nitrogen issupplied as two equal split doses at 30 and 45 DAT. In addition to NPK, sulfur is an important plant nutrient for onion crops, as it increases production and onion bulb pungency. Sulphur is applied as a basal dose @15kg/ha for soils showing sulphur level more than 25kg/ha and 30 kg of sulphur is applied per hectare for soils showing sulphur level less than 25 kg/ha (Source: DOGR, Pune). Meher *et al*. (2018) reported that sulphur application @40-60 kg/ha has shown better growth, high pungency, high bulb diameter due to optimum S utilization and high bulb yield. For the long-day onion, sulphur @ 50 kg/ha is applied in the soil as per the recommendation of DOGR, Pune. Al-Fraihat, *et al*. (2009) stated that the usage of nitrogen @ 200 kg /ha combined with sulphur @ 100 kg /ha has markedly boosted the yield and quality of onion. Nitrogen has shown better vegetative growth and marketable bulb yield. Sulphur plays a prominent role in protein and hormone formation, synthesis of vitamin and Amino acids

Micronutrient Management

In addition to primary macronutrient sources, some

Table 1. Impact of INM in onion

Nutrient source	Influence of INM based nutrient sources	References
Biofertilizers (*Azotobacter chroococcum* and *Azospirillum brasilianse*- applied as root dip treatment @1 kg/10 l of water 20 minutes before planting followed by soil application @ 2kg/ha 30 days after transplanting)+50% of recommended nitrogen source through Organic nitrogen fertilizers (10 t/ha of Farmyard manureor 2.5 t/ha of vermicompost)+ 50% of the recommended dose of nitrogen through chemical fertilizers.	Augmented crop growth and yield parameters in onion crop. It has emphatically increased the plant height, the number of leaves per plant, dry matter accumulation in bulbs and yield parameters like bulb diameter, bulb weight, and quality of bulb. Overall yield increased about 22%	Jayathilake *et al.* (2006)
FYM (Farm Yard Manure-3t/ha) + 30: 13: 25 kg/ha of N. P_2O_5 and K_2O + 15 N kg/ha of sulfate of ammonia)	Increased foliage weight, plant height, bulb diameter, a high number of bulbs, more number of firm bulbs, and a high marketable yield. Increased yield by about 34.1%.	Abbey and Kanton (2004)
100 % of organic nitrogen source supplied to the crop through the combined FYM + Neem seed cake + Vermicompost + Azotobacter + Phoshorous solubilizing bacteria (PSB) and sunhemp was grown as a trap crop	Improved the soil fertility status as well as crop yield in Onion	Khang *et al.* (2011)
Half the dose of nitrogen through FYM + half the dose through NPK inorganic fertilizers [suggested dose for onion was 100: 50: 50 kg ha^{-1} (N: P_2O_5:K_2O)]	Increased soil fertility, organic carbon content and decreased the electrical conductivity of soil	Khang *et al.* (2011)
Vermicast (2.5 t/ha)	Better crop growth and bulb yield	Moraka *et al.* (2006)

Table 2. Fertilizer schedule for Kharif onion (Bellary) with yield potential of 25-30 tonnes per hectare

Schedule	N	P_2O_5	K_2O	Organic manures
Basal dose	25 kg	40 kg	40 kg	Organic manures containing 75 Nitrogen perha (15 t of FYM per hectare, 7.5 t of poultry manure, and 7.5 t of vermicompost per hectare)
30 DAT	25 kg	-	-	-
45 DAT	25 kg	-	-	-
Total nutrient requirement for Kharif onion	75 kg	40 kg	40 kg	-

DAT- Days after transplanting.

micronutrients are necessary for providing better growth, quality, and yield attributes. They are also involved in the uptake of major nutrients, which help in activating various plant metabolic reactions. The deficiency of micronutrients could be overcome by applying nutrients either by foliar spray or soil application. Micronutrients needed for plant growth and development include iron, boron, manganese, molybdenum, zinc, copper, chlorine, and nickel. When the pH of the soil increases, deficiency of micronutrients occurs and hinders various physiological and biochemical activities of the plants. Zinc plays a starring role in enzyme formation and activates plant metabolism. As per the experimental studies of DOGR, ZnSO4 @10 kg/ha for Zn deficiency regions is recommended as a basal dose and borax @ 10kg/ha is recommended for boron deficient soils.

According to the studies of Aske *et al*. (2017), onion growth and yield parameters were on upper hand with soil application of 10 kg ha^{-1} of $ZnSO_4$, borax, and copper sulphate. Combined application of organic manures with chemical fertilizers would be a proper choice for attaining better plant growth soil fertility status. Farmyard manure @15t/ha and micronutrients containing 2.5% of Fe, 0.3% of Zn, 1% of Mn, 0.2% of B and 1.0% of Cu are applied as a foliar spray at 45^{th} and 60^{th} day after transplanting to increase the onion production. If the yield is found to be lower, three sprays of NPK fertilizer dose of 20:20:20 (complex commercial grade fertilizer) after 30, 45, and 60 days at 5g/l of water is recommended as a foliar application to obtain greater growth and yield of rabi onion (Shinde *et al.,* 2013). Ballabh *et al*. (2012) confirmed that the application of micronutrients such as Cu @2 mg/l, Fe @100 mg/l, Zn @ 4 mg/l and B @ 1 mg/l have resulted in a positive impact in promotin of growth and yield of onion. Foliar application of Fe (0.5%). B (0.1%), Zn (0.5 %), Mn (0.2%), and Cu (0.2%), along with the usage of biofertilizers *Azospirillum* and *Azotobacter* @ 5 kg/ha showed a positive effect on onion (Acharya, *et al*. 2015). Use of iron (2.5%), boron (0.5%), zinc (3%), copper (1%), and manganese (1%) have resulted in superior performance for growth and yield attributes besides increasing chlorophyll content as all these micronutrients like iron, copper, manganese, zinc, and boron are actively involved in the photosynthesis process and synthesis of chlorophyll (Pramanik *et al*., 2017). Foliar application of zinc and boron has shown a positive effect on nitrogen and potassium nutrient uptake while manganese application had resulted in better phosphorous and sulphur uptake (Panda and Mandal, 2018). Foliar spray of trace elements containing iron (2.5%), boron (0.5%), zinc (3%), copper (1%), and manganese(1%) at 30^{th} and 45^{th} day after planting had produced the positive effect on growth and yield parameters (Biswas *et al*., 2020).

Zinc and Boron

Zinc is a water-soluble fertilizer and essential micronutrient required for plants in fewer quantities, crucial for plant development. Zinc plays a vibrant role in the structural integrity of the membrane, protein synthesis, and gene expression. Boron is a vital micronutrient taking place in nitrogen absorption, cell division, protein, and carbohydrate metabolism which is essential for onion production. They also act as a regulator of plants' calcium and potassium ratio. It is an essential element for the formation of the cell wall. Zinc Sulphate 0.5% foliarspray resulted in an increased dry matter production, and bulb weight. Application of borax @ 10 kg/ha alone stemmed in the highest polar and equatorial diameter. Borax application of 5kg/ha in soil and through

Table 3. NPK recommendation for Bellary onion with yield potential of 40 to 50 tonnes/ hectare

Schedule	N	P_2O_5	K_2O	Organic manures
Basal dose	40 kg	40 kg	60 kg	Organic manures containing 75 Nitrogen per ha(15 t of FYM per hectare, 7.5 t of poultry manure and 7.5 t of vermicompost per hectare)
30 DAT	35 kg	-	-	-
45 DAT	35 kg	-	-	-
Total nutrient requirement for Kharif and Rabi onion	110 kg	40 kg	60 kg	-

DAT- Days after transplanting.**Source**: ICAR- Directorate of Onion and Garlic Research, Pune.

0.2% foliar application of borax showed more number of bulblets per clump. The findings of works by Dake *et al*. (2011), Manna *et al*. (2013), and Acharya *et al*. (2015) confirmed that zinc and boron gave rise to in an increased vegetative growth in onion. This may be due to the involvement of these micronutrients in cellular division and cell enlargement. Findings of Acharya *et al*. (2015) revealed that foliar spray of zinc and boron @ 1 kg/ha and 5 kg/ha combined with soil test-based recommended dose of fertilizers recorded better results in both growth and yield parameters like bulb quality, TSS, and bulb yield. Bulb yield in this study was higher as zinc is involved in the activation of enzymes involved in carbohydrate metabolism.

Smriti *et al*., (2002) reported that the application of boron to onion crops has amplified various yield attributes. Boron modulates the activities of ascorbate and dehydroascorbate, which leads to a loss of cell walls, allowing onions to grow more freely and increase their elongation and meristematic regions. Many studies showed that boron application was found to intensify plant height, leaf length, and the number of leaves of onion. Combined foliar spray of boron and zinc @ 0.3 kg/ha and 0.7 kg/ha after five months of sowing resulted in enhanced yield and yield parameters in seed production of onion.

Nano Fertilizers

Nanotechnology is an atom by atom manipulation that yields precise processes and products for the smart delivery of inputs needed for plants. According to Mikkelsen *et al*.(2018), nanofertilizers are grouped into nanoscale additives, nanoscale fertilizers, and nanoscale coatings. Plant nutrients are encapsulated in nano-based carrier materials and delivered to plants as nano-emulsions. These nanoparticles havea high surface area to volume ratio, high absorption capacity, and well-ordered nutrient release, making them easily available to plants. Nano-based fertilizers are otherwise called nanoformulations which release the active ingredients in response to biological need and environmental stress. Nanofertilizers are given to plants either through aeroponics and hydroponics or through foliar or soil application. The application of these nano fertilizers helps improve seedling growth, nitrogen metabolism, carbohydrate and protein synthesis, photosynthetic activity, tolerance to abiotic stress factors, quality improvement, balanced nutrient supply, soil fertility status, microbial flora, and water holding capacity. Laware, *et al*. (2014) have investigated that foliar application of Zinc oxide nanoparticles at 20 and 30 µg/ml in onion has resulted in increased seed weight per umbel, high 1000 seed weight, better plant growth, and induced early flowering than untreated plants. Tymoszuk, *et al*.(2020) have studied the effect of seed treatment of zinc oxide nanoparticles in *in-vitro* germination and seedling growth of *Allium cepa L.* and results showed a significant increase in seedling height, weight of leaf and roots. Seed treatment of zinc oxide nanoparticles enriched the seed germination in onion and showed improved performance for seedling characters. Application of copper oxide nanoparticles at 75-300 mg/kg in green onion (*Allium fistulosum)* enhanced the allicin, calcium, iron, magnesium, and manganese content and increased the reactive oxygen species (Wang *et al*., 2020). Fouda *et al*. (2020) reported that application of silver nanoparticles at 100 ppm in onion considerably lifted the yield.

Biostimulants

Biostimulants are synthetic or natural substances applied to plants through soil or seed, which causes a change in plants' physiological processes, resulting in increased nutrition efficiency, quality attributes, and tolerance to abiotic stresses. Biostimulants are gibberellic acid, cytokinin, indole butyric acid, butyric acid, humic acid, seaweed extract, fish aminoacid, and plant-based extracts. According to Amin *et al*. (2011), foliar application of glutamine and putrescine has resulted in increased quantity and quality of onion bulbs. Szczepanek *et al*. (2017) reported that foliar spray of seaweed extract resulted in increased chlorophyll index, fresh bulb weight, and fresh root weight of onion. These biostimulants enhanced growth and yield parameters and seaweed granule application in the soil prevents disease occurrence like downey mildew and Alternaria leaf spot of onion. Soil application of humic acid increased water holding capacity, yield, and tolerance to abiotic stresses (Sajid *et al*., 2012). The growth, yield, and qualityof onion was enhanced by foliar application of humic acid (Geries, 2013). Mogor *et al*. (2021) reported that application of calcareous marine alga *Lithothamnium sp*., a natural biostimulant showed auxin-like hormonal activity and increased the nutrient content, aminoacid content and total soluble protein content in onion. Semida *et al*. (2019) studied the effect of honey bee extract biostimulant on onion. They reported that the diluted honey bee extract application in onion has improved biomass production, water use efficiency, relative water content, membrane stability index, leaf photosynthetic pigments, osmoprotectants, and enzymatic nonenzymatic antioxidants as well as increased bulb yield of onion. These bio stimulants are also a good supplier of mineral nutrients and phytohormones. Bettoni *et al*. (2016) investigated that humic acid application in onion as the foliar spray had shown increased pseudostem diameter of more than 10 mm, improved shoot fresh mass, root and shoot dry mass. Humic acid spray in onion had increased leaf, root and bulb characters (Al-Fraihat *et al*., 2018). Abbas *et al*. (2020) investigated the effect of seaweed extract biostimulant on the yield and quality of various onion cultivars and found in increased leaf length, leaf width, plant height, and root length of onion. Hidangmayum *et al*. (2017) investigated the influence of seaweed liquid extract of *Ascophyllum nodosum* on onion. They reported that 0.50 % of the biostimulant extract elevated height, crop growth rate, number of leaves, bulb fresh weight, harvest index, chlorophyll a and b, leaf protein content, bulb protein content and high bulb yield in onion. Younes *et al*., (2021) have reported that liquorice root extract application in onion acts as a biostimulant and elevates the growth, yield, and quality parameters in onion. They have also shown improved nutritional status, total soluble carbohydrates, proline level, water-soluble proteins and activated the enzymatic and non-enzymatic antioxidants level in onion bulbs. Ragulraj *et al*., (2021) investigated the effect of foliar spray of three bio-stimulants such as Humic acid, Sea weed extract and Fish Amino acid on the growth, yield and quality of aggregatum onion. The experimental results revealed that humic acid @ 0.3% recorded the dominant results of maximum plant height (41.30 cm), neck thickness (1.067cm), dry matter (1.20g), average bulb weight (33.25g), total yield (14.41 tonnes/ha) and Benefit: Cost Ratio (BCR) (3.44), which was followed by humic acid 0.3%. This would be due to the fact that humic acid-treated plants might have exhibited better physiology in terms of respiration and photosynthetic activity, producing greater plant vigor and a great source for sink during bulbing. Auxin present in humic acid and seaweed extract would have triggered cell division that boosted the plant height and also promoted the root characteristics. Whereas the presence of cytokinin might be responsible for better yield characteristics in Sea Weed Extract. Fish amino acid resulted in better leaf growth and vegetative characteristics, leading to early maturity. In post-harvest analysis, humic acid and seaweed extract provided good marketable bulbs with less rotting percentage than fish amino acid and control. Eventually, cost economic analysis indicated that foliar spray of humic acid and seaweed extract exhibited increased benefit: cost ratio, irrespective of their concentrations, besides, they are cost-wise cheap and affordable.

Conclusion

Recent studies have estimated that continuous application of the high amount of inorganic fertilizers at single stretch results in reduced soil organic matter content, degrades the soil microbial consortia, nutrient imbalance to the crops, and affects the environment by causing land pollution. Continuous supply of inorganic nitrogen causes soil acidification and harms the soil microorganisms. Plant requirements for inorganic nitrogenous fertilizers can be lowered using INM approaches, and a reduction in the usage of purchased fertilizers can result in significant cash savings for small farmers. Due to increased fertilizer cost and imbalance nutrition to crops, INM approaches are found to be ecologically sound and economically viable. Hence, combining nutrient sources from organic manures, plant residues, biofertilizers, and chemical fertilizers would result in high nutrient use efficiency and improve the soil properties physically, biologically, and chemically by narrowing down the gap between nutrient removal and supply. Hence, to attain high crop productivity, minimize nitrogen loss, green house gas emission and attain high crop productivity, an ecologically sound nutrient management practices by the efficient blending of organic and inorganic nutrient sources is essential. The INM approach offers "win-win" opportunities for increasing crop yield and soil fertility while lowering environmental impact. In the future, INM can be considered a viable nutrient management concept in agriculture for ensuring food security and also improving environmental quality around the world, particularly in developing nations.

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