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Review Article
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NANO FERTILIZER: ITS IMPACT ON CROP GROWTH AND SOIL HEALTH

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ABSTRACT

Recent developments on application of nanotechnology in agriculture, plant mineral nutrition, soil health, and interactions with soil micro-flora directed to sustainable solutions by replacing traditional bulk fertilizers with their nano-particulate counterparts possessing superior properties to overcome the current challenges of bioavailability and uptake of minerals, increasing crop yield, reducing fertilizer wastage, and protecting the environment. Several studies showed that nano-particles of essential minerals and nonessential elements affected plant growth, physiology, and development, depending on their size, composition, concentration, and mode of application. It was reported that nano-particles and nano-tubes in numerous crops like sunflower, common bean, and maize enhanced germination and seedling growth, physiological activities including photosynthetic activity and nitrogen metabolism, mRNA expression and protein level, and positive changes in gene expression, indicating their potential use for increasing crop yields. The creation and improvement of fertilizers at nanoscale dimensions could have a profound impact on energy, the economy and the environment. Speculation not withstanding, the scientific, technical, and agricultural projects linked with nano-fertilizers must include side effects in order to accurately determine progress and shape a sustainable future.

Indian population was recorded 683 million in the year of 1981 but at 2030, it will attain to 1475 million. To feed the projected population of 1.48 billion by 2030, India needs to produce 350 million tonnes of food grains. This upward trend indicated that development and use of new types of fertilizers are one of the few practical options of feeding projected global population of 9.6 billion in 2050 or more but without seriously jeopardizing the ecosystems and the environment. Therefore, it is imperative to identify and apply available innovative technologies in fertilizer research and development. Fertilizer is a critical input needed for increasing production of food grains and other agricultural commodities within the overall constraints of extremely limited scope for increasing land area under cultivation. The adoption of modern technology incorporating use of HYV seeds, irrigation and fertilizers in the late 60s provided the impetus for increasing production of food grains at an accelerated space. Over the last 35 years, additional nutrients applied as manufactured fertilizers have been responsible for 50-55 per cent of the yield increase in developing countries including India. Nitrogen, phosphorous and potash, the three primary nutrients are required in large quantities by plants for sustaining life and their healthy growth. With intensification of agriculture and improvement in productivity levels, the removal of secondary and micronutrients has gone up many folds leading to multiple nutrient deficiencies well beyond the NPK scenario, which in fact are major constraints to achieve higher production. Though the consumption of chemical fertilizers is increasing steadily over the years, the use efficiency of nutrients applied through fertilizers continues to remain low, for N (30-40%), P (15-20%), K (50-55%), and micronutrients (2-5%), owing to nutrients losses from soils or conversion of nutrients into slowly cycling / recalcitrant pools within the soils. In India, fertilizer use efficiency is declining over the years. The greatest concern is to make increased fertilizer use more sustainable, attractive and profitable to the farmer. Attempts have been made all over the world to increase fertilizers use efficiency, but not much headway has been achieved. In this context, there would be greater importance of the information how to increase the nutrient use efficiency of fertilizers by the application of nanotechnology in the coming years. Lal (2008) narrated that amongst the numerous applications of nanotechnology in soil science use of nano-fertilizer is the emerging field to study upon. Nano-fertilizer may be defined as the nano particles, which can supply essential nutrients for plant growth, have higher use efficiency and can be delivered in a timely manner to a rhizospheric target or by foliar spray (Adhikari *et al.,* 2010). Nano particles have extensive surface area

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and capable of holding abundance of nutrients and release it slowly and steadily such that it facilitates uptake of nutrients matching the crop requirement without any associated ill- effects of customized fertilizer inputs. Currently production of slow- release and super sorbent nitrogenous and phosphatic fertilizers are of high demand in the agricultural sector. Several research workers of different countries have started their investigations to produce highly productive nano-fertilizers to boost agricultural production. Xiu *et al.*, (2006) reported that the natural kaoline and abandoned foam plastics could be used to prepare nano-subnano composites through the methods of organic material intercalation, semi emulsification, and cut at high velocity techniques for the preparation of cementing and coating of nanosubcomposites of slow / controlled –release fertilizers. Soil health has been defined as the capacity of soil to function as a living system, with ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots; recycle essential plant nutrients; improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production (FAO, 2008). (Kibble White *et al.*, 2008). proposed that soil health is dependent on the maintenance of four major functions: carbon transformations; nutrient cycles; soil structure maintenance; and the regulation of pests and diseases. They explained that each of these functions is manifested as an aggregate of a variety of biological processes provided by a diversity of interacting soil organisms under the influence of the abiotic soil environment. A combination of soil physical, chemical and biological properties Soil physical properties such as soil texture, aggregation, moisture, porosity, and bulk density; chemical properties such as total C and N, mineral nutrients, organic matter, cation exchange capacity (CEC); and soil biological properties such as microbial biomass C and N, biodiversity, soil enzymes, soil respiration, in addition to macro and meso-fauna can be used (Fabial *et al.*, 2014). Biological indicators are central to soil health because they can influence both chemical and physical properties of the soil. Soil organisms are involved in nutrient mineralization and availability. Macro and meso-fauna may also influence physical properties such as porosity, aeration and water infiltration. For example, earthworms can modify soil structure and enhance nutrient availability. Estimation of microbial biomass and activity may provide information of potential nutrient status of the soil. Soil organic matter is an important component of the soil which determines soil productivity but mineralization of soil organic matter may be greatly reduced in the absence of soil microorganisms. Hence, microbial activity is an important soil health indicator. The effect of nano-particles on soil microbes depend on type of nano-particle. The antimicrobial effect of some nano-particles may affect plant-microbe relationships which have impact on plant nutrition and soil fertility. For example, CeO_2 nano-particle dramatically reduced levels of nitrogen fixing bacteria within root nodules on soybeans thereby reducing nitrogen fixation rates (Brandeburova *et al.*, 2017). Many studies have used earthworms as indicators of soil health (Durenkanp *et al.*, 2016) and explained that the effect of nano-materials on growth and survival of adult earthworms is negligible while some other studies reported that the reproductive activity of earthworms may be reduced by nano-materials.

Effect of nano-fertilizer on crop growth

The current growing awareness of the phenomenon and availability of inexpensive natural zeolites in the world has aroused considerable commercial interest on developing zeolite based nano fertilizer. Chuprova *et al.,* (2004) found the beneficial effects of zeolite fertilizers on mobile humus substances of Chernozem and on biological productivity of maize. In another study, a patented nano-composite consists of N, P, K and micronutrients and mannose and amino acids have been shown to increase the uptake and utilization of nutrients by grain crops (Jinghua, 2004). Bhattacharya *et al.*, (2004) reported that the balanced application of NPK along with S, Zn, B and Mo will be an effective solution for higher grain yield of pulses in red and lateritic soils. Adequate NPK fertilization increased green and blackgram yields by 13% and 38% over the control. Liu *et al.,* (2006) have shown that the organic material (polystyrene) intercalated in the layers of kaolinite clay form a cementing of nano and subnano-composites which are capable of regulating the release of nutrients from the fertilizer capsule. Thus nano-particles could be used in the membrane control release of nutrients. Recently, Sharmila Rahale (2011) has monitored the nutrient release pattern of nano-fertiliser formulations carrying nitrogen. The data have shown the nano-clay based fertilizer formulations (zeolite and montmorillonite with a dimension of 30-40 nm) are capable of releasing the nitrogen for a longer period of time (> 1000 hrs) than conventional fertilizers (< 500 hrs). Nanotechnology can be exploited to improve the efficiencies of native and added sources of nutrients. Nano-fertilizer technology improves the fertilizer use efficiency of crops. There is an increasing interest in the utilization of nano-porous zeolites in farming over the years because of current public concern about the adverse effects of chemical fertilizers on the agro-ecosystem (Ramesh *et al.,* 2010).These reports and patented products strongly suggest that there is a vast scope for the formulation of nano- fertilizers (De Rosa *et al.*, 2010). Nano-fertilizer may be a strategy to improve the nutrient use efficiency of crops and crop productivity.

Nitrogen nano - fertlizer

To overcome the problems associated with the nitrogen leaching during fertilization, different approaches such as polyolefin resin-coated urea, neem coated urea, sulphur coated urea were taken to control the N release. However, slow-releasing fertilizers are often expensive and the release of N is slow at the time of high N. N loss can also be reduced using cation exchanger as additives in fertilizer to control NH_4^+ release. The retention and timely release of needed nutrients by zeolite improves overall crop yield. Clinoptilolite zeolite (CZ), a porous mineral with high cation exchange capacity (CEC, up to 300 cmol(p+) kg^{-1}) and with great affinity for NH_4^+ (Ming and Mumpton, 1989), has been used to reduce NH_3 emission from farm manure (Amon *et al.,* 1997), and to eliminate NH_3 toxicity to plants (Gupta *et al.,* 1997). Amendment of clinoptilolite zeolite (CZ) to sandy soil has been reported to lower NO3" and $NH4^+$ concentrations in the leachate and to increase moisture retention in the soil due to increased soil surface area and CEC (Huang and Petrovic, 1994). Urea nitrogen has been the most used N-source due to lower cost per unit of N. But N use efficiency of urea may be reduced because of losses from agricultural system by volatilization of ammonia to atmosphere. This is one of the main factors responsible for the low efficiency of urea, and may reach extreme values, close to 80% of N applied. Ammonium retained by CZ is generally subjected to slow release through cation exchange and nitrification in soil (Kithome *et al.,* 1998). Clinoptilolite zeolite has been used to reduce NH3 emission from farm manures (Amon *et al.,* 1997) and as NH_4^+ loaded exchange fertilizer (Perrin *et al.,* 1998) because of its high CEC. Application of $(NH_4)_2SO_4$ loaded into CZ was observed to minimize N leaching and to increase N utilization by crops in sandy soils compared with $(NH_4)_2SO_4$ alone (Perrin *et al.,* 1998). Perrin *et al.,* (1998) stated that clinoptilolite not only improves nitrogen fertilization efficiencies, it also reduces nitrate leaching by inhibiting the nitrification of ammonium to nitrate. Lefcourt and Meisinger (2001) reported that zeolite has the potential for reducing ammonia volatilization by sequestering ammonium-N on exchange cites. An addition of 6.25% zeolite resulted in a 50 % reduction in ammonia volatilization. An additional potential advantage is that zeolite bound ammonium is a good slow-release N source for plants. Unlike the commonly used fertilizers, the plant-growth material dramatically reduces loss of nutrients to groundwater and the environment. The N-urea losses can also be reduced using zeolites as additives in the fertilizers to control the retention and release of NH_4^+. There are reports in the literature showing that the addition of zeolite to the source of N can improve the nitrogen use efficiency (Rehakova *et al.,* 2004). Li (2003) demonstrated the feasibility of using surfactant-modified zeolite (SMZ) using hexadecyltrimethyl ammonium as fertilizer carrier to control nitrate release, and concluded that SMZ is a good sorbent for nitrate, whereas slow release of nitrate is achievable. Bhardwaj and Tomar (2011) conducted laboratory batch experiments to investigate the sorption of nitrate from aqueous solutions using hydrothermally synthesized and surface modified zeolite nano particles. The ability of surface modification with hexadecyltrimethyl ammonium (HDTMA) and Dioctadecyldimethyl ammonium greatly enhance the sorption and slow release of nitrate. Latifah *et al.,* (2011) confirmed that mixing urea with zeolite and sago waste water had great advantage over urea alone as the mixture encouraged the formation of ammonium and available nitrate ions over ammonia. The mixture also improved retention of exchangeable ammonium and available nitrate within the soil. Recently, Sharmila Rahale (2011) had monitored the nutrient release pattern of nano-fertiliser formulations carrying nitrogen. They had shown that nano-fertilizer released nutrients up to 1200 hrs while conventional fertilizer could support only for 300-350 hrs. The data had clearly demonstrated that zeolite as nano-fertilizer could be an ideal strategy to promote N use efficiency.

Phosphatic nano-fertilizer

Phosphatic fertilizers are mainly manufactured from rock phosphate ores. In India, out of 260 million tonnes (MT) of recoverable reserves of rock phosphate approximately 20 Mt only have been estimated to be of high grade which are being mined by different government agencies for commercial purposes. The depletion of high grade phosphate ores has brought about a search for suitable economically viable technique/process for beneficiating available low grade phosphate reserves. In view of this, rock phosphate (HGRP3 and Stone 3) nano particle was prepared by grinding it in a high energy ball mill. Pot culture experiments, conducted with maize crop in four diverse soils (Vertisol, Alfisol, Aridisol and Inceptisol) indicated that crop utilization of P from nano rock phosphate was at par with that of P from single superphosphate (SSP) in Vertisol and Inceptisol, while the yield response to P from nano rock phosphate was marginally lower than to P from SSP in Alfisol and Aridisol, suggesting that rock phosphate nano particles could be utilized as a source of potential phosphatic fertilizer in the cultivation of crops (Adhikari *et al.*, 2014). Field experiments conducted with sorghum, finger millet and maize fertilized with nano rock phosphate in water suspension (265 lit ha^{-1}) stabilized with 150 ml of linear Alkyl Benzene Sulphonate (LAS), showed that mean yield of sorghum increased from 1350 kg ha^{-1} to 2180 kg ha^{-1}, finger millet yield increased from 640 to 986 kg ha^{-1} and maize yield increased from 3760 kg ha^{-1} to 5440 kg ha^{-1}, due to nano rock phosphate application. Hence yield response to P from nano RP was marginally lower than to P from SSP, but could be utilized as a cheaper source of phosphorus for plants. (Adhikari *et al.*, 2014). Sharmila Rahale (2011) studied the PO_4^- release pattern of surface modified using various nanoclays and zeolite in a percolation reactor. Nano- formulations have been shown to release phosphate for an extended period of 40-50 days and the conventional fertilizer let out nutrients only upto 10-12 days. The review of literature suggests that surface modified zeolite could be potential strategy to promote P use efficiency which hardly exceed 18- 20% in conventional system.

Potassic nano-fertilizer

Zhou and Huang (2007) reported that slow and steady release of K from nano-zeolite and gave the reason that it may be due to the ion exchangeability of the zeolites with selected nutrient cations, zeolites can become an excellent plant growth medium for supplying plant roots with additional vital nutrient cations and anions. Guo *et al.* (2008) suggested that the zeolite can be “recharged” by the addition of more dissolved nutrients. Their selectivity of ion exchange on zeolite was determined in an order of $K^+ > NH_4^+ > Na^+ > Ca^{2+} > Mg^{2+}$. Despite the fact that potassium fixation in soil and dynamic equilibrium collectively sustain the availability of potassium in soil, nanotechnology can further improve the availability and regulated release of nutrients. Adhikari *et al.,* (2010) reported that glauconite mineral converted into nano-particulate form by applying top-down approach through high energy ball mill, was an alternative source of potassic fertilizer. The release of potassium from glauconite nano-particle in soil was studied in a pot culture experiment. Selected plant physiological parameters namely electrical conductivity of plant cell, height, leaf area and nitrate reductase activity were also recorded maximum at 200 mg/kg^{-1} glauconite nano-particle treated soil. Overall, glauconite nano-particles could supply potassium throughout the growth period and enhanced biomass yield of maize plant without showing any K deficiency symptoms.

Secondary nutrients nano-fertilizer

Green house experiments were conducted to evaluate the effect of MgO nano particles spray on maize plant (*Zea mays* L.) in three phosphorus (P) deficient benchmark soils of India. Application of MgO nano particles spray enhanced the enzymatic activities like root phytase and phosphatase particularly in P deficient situation. With the application of both P doses and MgO nano particles spray increased the different growth parameters of plants like root length, root volume, dry weight of shoot and root etc. irrespective of soils. The results can enhance our understanding on the role of MgO nano particles spray in plant root exudation and as well as the availability of soil P (Adhikari *et al.*, 2016).

Micronutrients nano-fertilizer

Lin and Xing (2008) reported that zinc oxide nanoparticles were shown to enter the root tissue of ryegrass and improved the germination. Melendi *et al.,* (2008) conducted an elegant experiment and showed a visualization of carbon coated nanotubes in plant cells using pumpkin plants as the model crop. This is one of the classic studies that can be used as a guiding tool to develop smart nutrient delivery system for plants. An investigation was carried out to study the efficacy of zinc oxide nano particles (<100 nm) as a source of zinc to the plants against ionic form of zinc through zinc sulfate ($ZnSO_4$) salt in Hoagland solution culture. Findings indicated that plant roots might have the unique mechanism of assimilating nano-ZnO particles for its growth and development. Nano-ZnO particles (<100 nm) also governed the enzymatic activity of maize plant (Adhikari *et al.,* 2015). In order to supply the requisite amount of Zn to the plants, a protocol has been developed to coat the seeds of maize (*Zea mays* L.), soybean (*Glycine max* L.), pigeon pea (*Cajanas cajan* L.) and ladies finger (*Abelmoschus esculentus* L.) with nano scale (<100 nm) ZnO powder @ 25 mg Zn g^{-1} seed and @ 50 mg Zn g^{-1} seed. The germination test carried out with coated and uncoated seeds indicated better germination percentage (93-100%) due to ZnO coating as compared to uncoated seeds (80%). Pot culture experiment conducted with coated seeds also revealed that the crop growth with ZnO coated seeds were similar to that observed with soluble Zn treatment applied as $ZnSO_4.7H_2O$ (@ 2.5 ppm Zn). The most important advantage of seed coating with nano ZnO particle is that it did not exert any osmotic potential at the time of germination of the seed, thus, the total requirement of Zn of the crop can be loaded with the seed effectively through nano scale ZnO particle (Adhikari *et al.,* 2016). Application of Zn nano particles (<100 nm) at relatively lower level (0.28 ppm) enhanced the growth of maize plant as compared to normal $ZnSO_4$ (0.5 ppm). The plant parameters like, plant height, root length, root volume, dry matter weight were all improved due to application of zinc oxide nano particle. Plant root might have got the unique mechanism of assimilating nano-Zn and using for its growth and development (Adhikari *et al.*, 2015). Solution culture experiments were conducted to investigate the effect of CuO nano particles (<50 nm) on the growth and enzymatic activity of maize (*Zea mays* L.) plant. CuO nano particles can enter into the plant cell through roots and leaves. Bioaccumulation increased with increasing concentration of CuO nano particles (NPs), and agglomeration of particles was observed in the cells using transmission – electron microscopy. Application of CuO nano particles through solution culture as well as spray enhanced the growth (51%) of maize plant in comparison to control. The different enzymatic activities like glucose-6-phosphate dehydrogenase, succinate dehydrogenase, superoxide dismutase, catalase, guaiacol peroxidase were studied to find a possible pathway through which NPs may affect the enzymatic activity of plant. Amongst the enzymes, the activity of glucose-6-phosphate dehydrogenase was highly influenced by CuO nano particles application by spray as well as in solution. CuO nano particles affected the pentose phosphate pathway of maize plant (Adhikari *et al.,* 2014). SiO_2 and Mo nano particles are one of the major and frequently used engineered oxide nano particles. The potential effects of SiO_2 (10-20 nm) and Mo (<100 nm) nano particles on rice seed germination were studied. SiO_2 nano particles had showed no toxic effect on rice growth, whereas root growth and elongation were arrested with Mo nano particles after 50 mg L^{-1}. In many cases root necrosis was occurred. Massive adsorption of Mo nano particles into the root system was responsible for the toxicity. The uptake of both the nano particles was observed with rice seedlings. Application of silica nano particles enhanced the root length, root volume and dry matter weight of shoot and root of rice crop. This study showed that direct exposure to specific types of nano particles caused both positive and negative effects on plant growth. (Adhikari *et al.,* 2013). Cieschi *et al.* (2019) studied on eco-friendly iron-humic nanofertilizers synthesis for the prevention of iron chlorosis in soybean (*Glycine max*) grown in calcareous soils. Development and application of new fertilizers using nanotechnology are one of the potentially effective options of enhancing the iron humates, according to the sustainable agriculture. Particle size, pH, and kinetics constrain the iron humate efficiency. Thus, it is relevant to understand the iron humate mechanism in the plant–soil system linking their particle size, characterization and iron distribution in plant and soil using Fe as a tracer tool. Three hybrid nano-materials (F, S, and M) were synthesized as iron-humic nano-fertilizers (Fe-NFs) from leonardite potassium humate and Fe used in the form of Fe (NO) or Fe (SO).

Three doses (35, 75, and 150 ìmol pot) of each iron-humic material were applied to soybean iron deficient plants and their iron nutrition contributions were compared to Fe-EDDHA and leonardite potassium humate as control treatments. Ferrihydrite was detected as the main structure of all three Fe-NFs and the plants tested with iron-humic compounds exhibited continuous long-term statistically reproducible iron uptake and showed high shoot fresh weight. Moreover, the Fe from the humic nano-fertilizers remained available in soil and was detected in soybean pods. The Fe-NFs offers a natural, low cost and environmental option to the traditional iron fertilization in calcareous soils.

Effect of nano-fertilizer on soil health

Biosolids are predominantly disposed in land applications as organic fertilizer for crop production or land reclamation. Nano-particles were detected in wastewater and biosolids raising concerns about their effect on soil health and crop growth (Fayiga *et al.,* 2017). Carbon nano-tube as a plant growth regulator was tested to study its effect on tomato growth, reproductive system, and soil microbial community and showed that there was no signiûcant affect on bacterial diversity (Khodakovskaya *et al.,* 2013). Fabian Fernandez-Luqueno *et al.,* (2014) studied on effects of nano-fertilizers on plant growth and development, and their interrelationship with the environment. It was reported that nano-particles and nano-tubes in numerous crops clover, common bean, and maize, enhanced germination and seedling physiological activities including photosynthetic activity and nitrogen metabolism, mRNA ion and protein level, and positive changes in gene expression, indicating their potential use easing crop yields. Rajput *et al.,* (2018) investigated on effect of nano-particles on crops and soil microbial communities and concluded that increased concentration of nano-particles poses threat to beneficial communities as well as crops and soils. Thus, it is important to explore that whether nano-particles could compromise crop yields, soil properties, soil microbes, and functional activities of soils. Tian *et al.,* (2019) reviewed on the topic that are nano-particles are threat to mycorrhizal and rhizobial symbiosis. Soil microorganisms can be exposed to, and affected by nano-particles (NPs) that are either purposely released into the environment or reach soil as nano-material contaminants. It is crucial to evaluate the potential impact of NPs on key plant-microbe symbioses such as mycorrhizas and rhizobia, which are vital for health, functioning and sustainability of both natural and agricultural ecosystems. NPs may have neutral, negative, or positive effects on development of mycorrhizal and rhizobial symbioses. The net effect of NPs on mycorrhizal development is driven by various factors including NPs type, speciation, size, concentration, fungal species, and soil physicochemical properties. As expected for potentially toxic substances, NPs concentration was found to be the most critical factor determining the toxicity of NPs against mycorrhizas, as even less toxic NPs such as ZnO NPs can be inhibitory at high concentrations, and highly toxic NPs such as Ag NPs can be stimulatory at low concentrations. Likewise, rhizobia show differential responses to NPs depending on the NPs concentration and the properties of NPs, rhizobia, and growth substrate, however, most rhizobial studies have been conducted in soil-less media, and the documented effects cannot be simply interpreted within soil systems in which complex interactions occur. Overall, most studies indicating adverse effects of NPs on mycorrhizas and rhizobia have been performed using either unrealistically high NP concentrations that are unlikely to occur in soil, or simple soil-less media (e.g., hydroponic cultures) that provide limited information about the processes occurring in the real agroecosystems. To safeguard these ecologically paramount associations, along with other ecotoxicological considerations, large-scale application of NPs in farming systems should be preceded by long-term field trials and requires an appropriate application rate and comprehensive assessment of the context parameters i.e., the properties of NPs, microbial symbionts, and soil. Directions and priorities for future research are proposed based on the gaps and experimental restrictions identiûed. Frenk *et al.,* (2013) investigated on effect of metal oxide nano-particles on microbial community structure and function in two different soil types. Increased availability of nano-particle-based products will, inevitably, expose the environment to these materials. Engineered nano-particles (ENPs) may thus find their way into the soil environment via waste water, dumpsters and other anthropogenic sources; metallic oxide nano-particles comprise one group of ENPs that could potentially be hazardous for the environment. Because the soil bacterial community is a major service provider for the ecosystem and human kind, it is critical to study the effects of ENP exposure on soil bacteria. These effects were evaluated by measuring bacterial community activity, composition and size following exposure to copper oxide (CuO) and magnetite (Fe_3O_4) nano-sized (<50 nm) particles. Two different soil types were examined viz. a sandy loam (Bet-Dagan) and a sandy clay loam (Yatir), under two ENP concentrations (1%, 0.1%). Results indicated that the bacterial community in Bet-Dagan soil was more susceptible to change due to exposure to these ENPs, relative to Yatir soil. More specifically, CuO had a strong effect on bacterial hydrolytic activity, oxidative potential, community composition and size in Bet-Dagan soil. Few effects were noted in the Yatir soil, although 1% CuO exposure did cause a significant decreased oxidative potential and changes to community composition. Fe_3O_4 changed the hydrolytic activity and bacterial community composition in Bet-Dagan soil but did not affect the Yatir soil bacterial community. Furthermore, in Bet-Dagan soil, abundance of bacteria annotated to OTUs from the Bacilli class decreased after addition of 0.1% CuO but increased with 1% CuO, while in Yatir soil their abundance was reduced with 1% CuO. Other important soil bacterial groups, including *Rhizobiales* and *Sphingo bacteriaceae*, were negatively affected by CuO addition to soil. These results indicate that both ENPs are potentially harmful to soil environments. Furthermore, it is suggested that the clay fraction and organic matter in different soils interact with the ENPs and reduce their toxicity. Grun *et al.,* (2019) investigated on impact of silver nano-particles (AgNP) on soil microbial community depending on functionalization, concentration, exposure time, and soil texture. From their work, they got that the factors functionalization, concentration, exposure time, and soil texture significantly impacted the effect expression of AgNP on the soil microbial community. Especially long-term exposure scenarios are strongly needed for the reliable environmental impact assessment of AgNP exposure in various soil types. Sindhura *et al.,* (2013) studied on synthesis, characterization and evaluation of effect of phytogenic zinc nanoparticles on soil exo-enzymes. Biosynthesis of metallic nanoparticles is currently under exploitation. Use of plant and plant materials for the synthesis of zinc nanoparticles is relatively new and exciting research field. The biogenic zinc nanoparticles were synthesized using the leaves of *Parthenium hysterophorous* by green synthesis route. The synthesized zinc nanoparticles showed good enzymatic activity and microbial activity. The physiological parameters increased from 30 to 60 days of sowing when compared to control. Du *et al.,* (2011) investigated on ZnO nano-particles negatively affect wheat growth and soil enzyme activities in agricultural soil and concluded that the ZnO nano-particles dissolved in the soil, thereby enhancing the uptake of toxic Zn by wheat. The nano-particles also induced significant changes in soil enzyme activities, which are bio-indicators of soil quality and health. Soil protease, catalase, and peroxidase activities were inhibited in the presence of the nano-particles, urease activity was unaffected. The nano-particles themselves or their dissolved ions were clearly toxic for the soil ecosystem. Kahru *et al.,* (2010) reviewed on the topic from ecotoxicology to nanoecotoxicology and gave the view that different nano metal oxides at different concentration have different effect and usually at higher dose concentration, they show toxic effects. Rangaraj *et al.,* (2014) investigated on augmented biocontrol action of silica nanoparticles and *Pseudomonas fluorescens* bioformulant in maize (*Zea mays* L.) and reported that nano-silica and *Pseudomonas sp.* was treated in soil to enhance the bio-control activity against pathogens in maize. Burman *et al.,* (2013) investigated on effect of zinc oxide nano-particles on growth and antioxidant system of chickpea seedlings. Ten days old seedlings of chickpea (*Cicer arietinum* L var. HC-1) were foliar sprayed with 1.5 or 10 ppm aqueous solution of zinc oxide (ZnO) nanoparticles and effects were compared with corresponding concentration of zinc sulphate and ZnO of normal size. Maximum promontory response with respect to shoot dry weight was observed in seedlings treated with 1.5 ppm ZnO nano-particles while at 10 ppm the nano-particles exerted adverse effects on root growth. However, overall biomass accumulation improved in the ZnO nano-particle treated seedlings. This response may be attributed to low reactive oxygen species (ROS) levels which resulted in less lipid peroxidation as evident from lower malondialdehyde (MDA) content. This was associated with lower activity of prominent antioxidant enzymes, superoxide dismutase (SOD), and peroxidase ZnO nano-particle treated seedling compared to control. The study indicated importance in precise application of zinc, more so in deficient system, where plant response varies with concentration and is important in understanding the mechanism of action of specific nano-materials. Collins *et al.,* (2012) worked on assessing the impact of copper and zinc oxide nano-particles on soil and concluded that nano-particles have some environmental issues to be concerned. Morales-Diaz *et al.,* (2017) reviewed on application of nano-elements in plant nutrition and its impact in ecosystem and concluded that nano-elements have enhanced nutrient availability to plants but impact on ecosystem have to be researched. Ruttkay *et al.,* (2017) reported that the accumulation of NPs in the plant body, their quantification and localization is still very unclear and further research in this area is necessary.

CONCLUSION

Scientists are under enormous pressure to deliver technologies to increase yields that are not only technically reliable but cost-effective for the fertilizer industry and for farmers. Understanding specific applications of nano-materials in fertilizer is critical to preventing inadequately researched, field tested and regulated products from exacerbating current environmental and public health problems associated with industrial scale use of synthetic chemicals. The public has an important role to play to ensure that any new nano-fertilizer products are not rushed to market before their environmental and public health impacts can be determined, reliably validated, and diminished, if not eliminated, through regulation and product re-design. It remains to be seen whether nano-fertilizer researchers will be patient enough to learn from plant physiology and soil science the risk and hazards that some nano-materials may pose to soil, plant and human health. Nevertheless, additional research is necessary in order to understand the function of nano-fertilizers on the genetic, physiologic and morphologic changes in crops, as well as effect on soil microbial communities, symbioses, physicochemical soil properties and pollution.

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PHYSIOLOGICAL BASIS OF IMPROVED YIELDS IN RAINFED COTTON UNDER HIGH DENSITY PLANTING SYSTEM

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ABSTRACT

Rainfed crop cultivation suffers from water stress situation. Physiological traits evaluation enables identification of gaps in realizing the improved productivity. Field experiment was conducted to find out suitable plant density and genotypes under rainfed conditions of Telangana during *Kharif,* 2015-2016 and *Kharif* 2016-2017 at college farm, College of Agriculture, Rajendrangar, PJTSAU. The results clearly indicated that lower plant density at 75 x 10 cm plant spacing performed better in terms of chlorophyll content, SPAD values and photosynthetic rate than higher plant densities at 65 x 10 cm and 45 x 10 cm. Osmolites production like proline was found higher under low plant density at 75 x 10 cm.

Cotton is grown as a major commercial fibre crop in more than 30 countries worldwide with major contribution from China, India, United States and Pakistan, and is mostly cultivated in warmer regions (Riaz *et al.*, 2013). It is fourth most cultivated crop in Telangana state, covering 17.13 lakh hectares and 42.65 lakh tones of production during 2017. Telangana state has 50.3% (25.29 l ha) crop area under irrigation while, cotton covers 12.6% only (Ministry of Agriculture & Farmers Welfare, Govt. of India 2014-15). It is a tropical crop and growth of the crop is greatly influenced by macro and microenvironment. Being a Glycophyte, cotton has superior tolerance for abiotic stress than other commercial crops. Plant population in cotton cultivation has been identified as one of major factors responsible for low yield (Aziz *et al.,* 2011). The high density planting is an alternate cultivation system that can increase the productivity, profitability and minimizes the risks of India's conventional cotton cultivation.

MATERIAL AND METHODS

A field experiment was conducted for two consecutive crop seasons during *kharif,* 2015-2016 and 2016-2017 at college farm, College of Agriculture, Rajendrangar. The experiment was laid out in a split plot design with three replications. Nine genotypes of cotton collected from various regions of Telangana, were sown in three spacings of 75 X 10 cm, 60 X 10 cm and 45 X 10 cm which accommodated 133333, 166666 and 222222 plants per hectare respectively. The SPAD-502 (Soil Plant Analytical Development) meter was used for measuring the relative chlorophyll content of leaves. The chlorophyll content was measured from fully expanded leaves. Mean of five values from five leaves was obtained. The observations were recorded at 40, 60 and 90 DAS. Chlorophyll content in leaves was estimated colorimetrically by 80 % Acetone method (Arnon, 1949). The photosynthetic rate was measured by using Infra Red Gas Analyser (Model TPS-1) from leaves that had fully expanded recently. The net exchange of CO_2 between a leaf and the atmosphere was measured by enclosing the leaf in closed chamber and monitoring the rate at which the CO_2 concentration in the chamber changed over a fairly short time interval. Proline content in the leaves was determined following Bates *et al.,* (1973) method. Zhang *et al.,* 2015, reported that overexpression of *GhAnn*1, a cotton annexin gene, enhanced the tolerance to drought and salt by increasing the activity of superoxide dismutase (SOD) and elevated levels of proline and soluble sugars.

RESULTS AND DISCUSSION

The Chlorophyll content determines the photosynthetic capacity and influence the rate of photosynthesis, dry matter product and yield. It indicates physiological status of plant and is fundamentally essential pigment for conversion of light energy into

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Table 1. SCMR (SPAD chlorophyll meter readings) values at different growth stages of cotton genotypes under different plant spacings

	Square stage				Flowering stage				Boll initiation stage			
	75 x 10	**60 x10**	**45 x10**	**Mean**	**75 x 10**	**60 x 10**	**45 x10**	**Mean**	**75 x 10**	**60 x 10**	**45 x 10**	**Mean**
WGCV-48	36.1	31.2	29.5	32.3	41.8	40.1	37.3	39.7	40.0	34.4	34.2	36.2
NDLH-1938	32.8	32.8	27.1	30.9	38.9	37.6	33.6	36.7	34.1	33.5	32.4	33.3
H-4492859	30.5	33.2	29.4	31.0	38.1	36.8	35.5	36.8	34.7	32.9	32.6	33.4
Suraj	34.8	32.7	28.9	32.1	40.3	39.5	35.7	38.5	35.0	32.9	33.6	33.8
ADB-39	23.2	28.5	23.1	24.9	35.3	31.7	29.7	32.2	31.5	29.1	30.6	30.4
Anjali	28.3	27.4	25.0	26.9	36.2	35.3	32.0	34.5	32.9	31.3	33.9	32.7
ADB-542	26.4	31.3	25.6	27.8	31.6	28.2	25.0	28.3	32.1	28.0	29.7	29.9
Narasimha	36.6	33.1	31.5	33.7	36.1	32.5	29.2	32.6	30.9	28.6	30.7	30.1
Deltapine-9121	42.5	35.6	32.4	36.8	41.8	38.9	33.7	38.1	39.6	33.4	32.8	35.3
Mean	32.4	31.8	28.1	30.7	37.8	35.6	32.4	35.3	34.5	31.6	32.3	32.8
Comparison	**Std. Error**		**C.D.**		**Std. Error**		**C.D.**		**Std. Error**		**C.D.**	
Si – Sj	0.73		2.18		1.88		5.64		0.49		1.46	
Gi – Gj	0.38		1.09		0.66		1.91		0.44		1.25	
SiGi – SiGj	1.14		3.29		1.99		5.72		1.31		3.75	
SiGi – SjGi	1.18		3.46		2.49		7.33		1.17		3.39	

chemical energy. Singh (2015) evaluated the effect of drought stress on chlorophyll content in crop plants and found that chlorophyll content decreased with decreasing the irrigation water. The data pertaining to productivity of genotypes at different planting densities had significant effect on chlorophyll content (table 1). Chlorophyll content increased steadily up to flowering stage and later decreased following a standard growth curve. In the flowering stage, maximum chlorophyll content was observed in wide spacing of 75 x 10 cm (2.64 mg g^{-1} of fresh tissue). The genotype Delatapine 9121 exhibited maximum chlorophyll content (3.4 mg g^{-1} of fresh tissue) followed by WGCV 48 (3.07 mg g^{-1} of fresh tissue) at flowering stage and minimum content was recorded in Narasimha (1.67 mg g^{-1} of fresh tissue). Maximum chlorophyll content (3.6 mg g^{-1} of fresh tissue) was recorded in Delatapine 9121 at flowering stage under 75 x 10 spacing. These findings are in accordance with Singh (2015).

Leaf nitrogen status is normally manifested with the leaf chlorophyll content. There was a significant difference in SCMR values among the genotypes, and among the spacings at all the growth stages of the crop. SCMR values steadily increased upto boll initiation stage and decreased thereafter. Wider spacing recorded higher SPAD value as compared to closer spacing. The genotypes WGCV 48 and Deltapine 9121 dominated for SCMR values among others at all three stages of crop phenology. Maximum SCMR was reported by WGCV 48 (36.2) followed by Deltapine 9121 (35.3). Among spacings 75 X 10 cm (34.5) had maximum SCMR than other spacings. The interaction of WGCV 48 at boll initiation stage under 75 x 10 cm has yielded maximum SCMR over all other combinations. The higher values of SCMR attributed for increased photosynthetic rate and dry matter production and higher productivity. Akhtar *et al.*, 2010, in his study observed chlorophyll degradation and growth reduction in cotton plants under salt stress.

There were significant differences in photosynthetic rate among various genotypes and among the spacings as well. Photosynthetic rates of plants were increased up to boll initiation stage after which slowly decreased (table 2). This is attributed to decreased photosynthetic pigments and enhanced reactive oxygen species production after physiological maturity of the plant. Maximum photosynthetic rate was recorded at boll initiation stage (23.7 i mol CO_2 m^{-2} s^{-1}) and genotype Deltapine 9121 (26.8 i mol CO_2 m^{-2} s^{-1}) recorded maximum values and genotype Narasimha recorded minimum photosynthetic rate of 20.6 i mol CO_2 m^{-2} s^{-1}. The combination of Deltapine 9121 at boll initiation stage under 75 x 10 cm spacing had exhibited maximum photosynthetic rate (29.9 i mol CO_2 m^{-2} s^{-1}) than all other combinations.The transgenic cotton plants with enhanced glycinebetaine accumulation were more tolerant to drought stress than normal genotypes and had increased photosynthesis, relative water content, increased osmotic adjustment, lower lipid membrane peroxidation and a lower percentage of ion leakage (Lv *et al.*, 2007).

Proline content was significantly influenced by different HDPS spacings and genotypes (Table 3). Under 75 x 10 cm spacing, maximum proline content was recorded in genotype Deltapine 9121 in all three phenophages of crop (123.9, 500.4 and 746.5 ig g^{-1} fresh weight) and minimum at boll development stage in genotype Anjali (332.8 ig g^{-1} fresh weight). Significant effect of spacings on the proline content was reported by Singh *et al.,* (2015). Decline in the level of proline content in the leaves of plants subjected to 38 and 45°C temperatures as compared to the control plants (30°C) was reported by Gur *et al.,* 2010.

High seed cotton yield of upland cotton is related to higher fruiting coefficient, medium leaf area, optimum amount of dry matter, low to medium photosynthetic rate and high to medium boll number and boll weight (Bharadwaj *et al.*, 1971). Higher yield per plant was supported by more number of bolls per each plant and higher boll weight. The yield of cotton genotypes was significantly influenced by different plant spacings. Maximum seed cotton yield was recorded by Deltapine 9121 (23.17 g $plant^{-1}$) in wider row spacing of 75 X 10 cm and minimum was by Narasimha (5.6 g $plant^{-1}$) under closer row spacing of 45 X 10 cm. Seed cotton yield increased with increased dose of organic and inorganic fertilizers under high density plant population (Ushanandini *et al.,* 2017).

Singh *et al.,* (2012) reported a positive correlation of seed cotton yield with plant geometries. Wider spacing of 67.5 x 90 cm recorded maximum seed cotton yield (2387 kg ha^{-1}) and closer spacing of 67.5 x 75 cm was recorded with minimum seed cotton yield

Table 2. Total Chlorophyll Content (mg g^{-1} of fresh tissue) values at different growth stages of cotton genotypes under different plant spacings

	Square stage				Flowering stage				Boll initiation stage			
	75 x 10	60 x10	45 x10	Mean	75 x 10	60 x 10	45 x10	Mean	75 x 10	60 x 10	45 x 10	Mean
WGCV-48	2.49	3.05	2.50	2.68	3.4	3.1	2.7	3.07	2.55	2.68	2.34	2.52
NDLH-1938	2.14	1.59	1.51	1.75	3.1	2.6	2.2	2.63	2.28	2.43	2.41	2.37
H-4492859	1.80	1.28	1.14	1.41	2.1	1.6	1.5	1.73	1.96	1.62	1.72	1.77
Suraj	2.45	1.74	1.89	2.03	2.7	2.9	2.5	2.70	2.40	2.24	2.35	2.33
ADB-39	1.67	1.46	1.09	1.41	2.3	1.9	1.8	2.00	1.77	1.53	1.59	1.63
Anjali	1.68	1.49	1.18	1.45	2.5	2.1	2.2	2.27	1.68	1.97	1.96	1.87
ADB-542	1.71	1.44	1.08	1.41	2.3	1.9	1.8	2.00	1.93	1.69	1.32	1.65
Narasimha	1.54	1.20	1.01	1.25	1.8	1.7	1.5	1.67	1.34	1.26	0.98	1.19
Deltapine-9121	3.04	2.38	1.93	2.45	3.6	3.4	3.2	3.40	3.20	3.16	2.70	3.02
Mean	2.06	1.74	1.48	1.76	2.64	2.36	2.16	2.39	2.12	2.06	1.93	2.04
Comparison	**Std. Error**		**C.D.**		**Std. Error**		**C.D.**		**Std. Error**		**C.D.**	
Si – Sj	0.075		0.226		0.037		0.112		0.063		0.189	
Gi – Gj	0.023		0.065		0.019		0.055		0.026		0.076	
SiGi – SiGj	0.068		0.195		0.057		0.164		0.079		0.227	
SiGi – SjGi	0.094		0.276		0.060		0.174		0.090		0.265	

Table 3. Photosynthetic rate (ì mol CO$_2$ m^{-2} s^{-1}) values at different growth stages of cotton genotypes under different plant spacings

	Square stage				Flowering stage				Boll initiation stage			
	75 x 10	60 x10	45 x10	Mean	75 x 10	60 x 10	45 x10	Mean	75 x 10	60 x 10	45 x 10	Mean
WGCV-48	11.9	11.2	10.3	11.1	19.3	17.4	15.3	17.3	27.6	25.4	24.9	25.9
NDLH-1938	10.5	9.9	8.9	9.8	17.0	15.6	14.3	15.6	25.4	22.9	23.5	23.9
H-4492859	9.2	8.5	8.5	8.7	17.0	16.0	14.7	15.9	25.2	22.8	22.0	23.3
Suraj	10.2	9.3	8.3	9.3	16.2	15.3	13.4	15.0	26.5	23.9	23.3	24.5
ADB-39	9.7	9.3	8.1	9.0	16.1	14.7	12.8	14.5	24.6	24.0	23.1	23.9
Anjali	9.0	8.3	7.7	8.3	15.7	14.4	13.2	14.4	24.6	22.5	21.5	22.9
ADB-542	9.9	9.0	8.1	9.0	16.8	15.7	12.7	15.1	23.5	22.0	20.2	21.9
Narasimha	9.4	8.2	7.8	8.5	16.5	15.3	13.1	15.0	22.7	20.3	18.8	20.6
Deltapine-9121	13.7	12.1	10.9	12.2	22.2	19.8	17.0	19.7	29.9	26.4	24.3	26.8
Mean	10.4	9.5	8.7	9.6	17.4	16.0	14.1	15.8	25.5	23.3	22.4	23.7
Comparison	**Std. Error**		**C.D.**		**Std. Error**		**C.D.**		**Std. Error**		**C.D.**	
Si – Sj	0.24		0.73		0.23		0.69		0.35		1.06	
Gi – Gj	0.13		0.36		0.15		0.42		0.23		0.66	
SiGi – SiGj	0.38		1.09		0.44		1.27		0.69		1.98	
SiGi – SjGi	0.39		1.15		0.43		1.25		0.66		1.93	

Table 4. Proline ($\mu g\ g^{-1}$ fresh weight) content at different growth stages of cotton genotypes under different plant spacings

	Square stage					Flowering stage			Boll initiation stage			
	75 x 10	**60 x10**	**45 x10**	**Mean**	**75 x 10**	**60 x 10**	**45 x10**	**Mean**	**75 x 10**	**60 x 10**	**45 x 10**	**Mean**
WGCV-48	51.5	73.8	81.6	69.0	293.2	354.1	385.7	344.3	407.6	561.3	831.8	600
NDLH-1938	43.7	67.8	78.3	63.3	276.5	324.8	311.6	304.3	365.1	507.0	788.0	553.4
H-4492859	36.5	56.0	69.6	54.0	252.1	251.6	270.6	258.1	339.1	452.0	787.2	526.1
Suraj	51.7	72.0	78.3	67.3	279.6	340.8	355.2	325.2	390.8	523.9	820.2	578.3
ADB-39	41.6	59.4	70.4	57.1	259.3	255.9	288.9	268.0	365.8	460.7	749.7	525.4
Anjali	37.7	56.5	69.4	54.5	227.1	273.0	301.3	267.1	332.8	427.2	731.3	497.1
ADB-542	82.6	77.6	74.4	78.2	329.0	278.6	275.2	294.3	414.9	437.1	551.3	467.8
Narasimha	72.5	79.0	78.0	76.5	325.9	294.7	270.8	297.1	422.7	437.5	587.1	482.4
Deltapine-9121	127.1	128.2	116.5	123.9	530.9	511.7	458.5	500.4	707.0	706.6	825.9	746.5
Mean	60.5	74.5	79.6	71.5	308.2	320.6	324.2	317.7	416.2	501.5	741.4	553.0
Comparison	**Std. Error**		**C.D.**		**Std. Error**		**C.D.**		**Std. Error**		**C.D.**	
Si – Sj	3.12		9.36		10.03		30.06		15.39		46.13	
Gi – Gj	1.21		3.46		6.98		20.01		8.42		24.14	
SiGi – SiGj	3.62		10.39		20.93		60.04		25.25		72.42	
SiGi – SjGi	4.30		12.63		19.82		57.50		25.73		74.98	

Table 5. Seed Cotton Yield (g plant^{-1}) of cotton genotypes under different plant spacings

	Seed Cotton Yield			
	75x 10	**60 x10**	**45x10**	**Mean**
WGCV-48	18.4	13.8	9.7	14.0
NDLH-1938	15.8	12.7	8.4	12.3
H-4492859	15.7	11.4	7.7	11.6
Suraj	14.9	11.6	7.7	11.4
ADB-39	13.5	11.0	6.6	10.4
Anjali	14.2	10.1	6.0	10.1
ADB-542	16.6	11.3	7.1	11.7
Narasimha	12.8	9.4	5.6	9.3
Deltapine-9121	23.2	15.4	9.8	16.3
Mean	16.1	11.9	7.6	

Comparison	Std. Error	C.D.
Si – Sj	0.25	0.98
Gi – Gj	0.11	0.34
SiGi – SiGj	0.19	0.60
SiGi – SjGi	0.29	1.10

(2218 kg ha^{-1}). The wider spacing led to decreased plant population per hectare but increment of boll number per plant and boll weights had contributed to achievement of higher over all yields. Aziz *et al.,* (2011) reported maximum seed cotton yield of 2.93 ton ha^{-1} under 75 X 45 cm spacing and minimum (0.96 ton ha^{-1}) under 90 × 45 cm spacing. Venugopalan *et al.,* (2014) reported 25-30% higher yield at high densities *viz.*, 1.5 to 2.5 lakh plants ha^{-1} at 45 or 60 cm spacing over the recommended spacing, under rainfed condition.

The wider row spacing of 75 X 10 cm enabled the maximum expression of physiological performance of Deltapine 9121 followed by WGCV 48. The physiological parameters like higher chlorophyll content, SCMR values, increased photosynthetic efficiency and increased osmolites production under moisture stress were attributed to higher overall performance of cultivars under wider row spacing.

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Research Article
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INFLUENCE OF TILLAGE PRACTICES AND RESIDUE MANAGEMENT PRACTICES ON YIELD ATTRIBUTES AND YIELD OF MAIZE IN MAIZE-BASED CROPPING SYSTEMS UNDER SEMI-ARID TROPICS

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ABSTRACT

A field experiment was conducted during *kharif* and *rabi* in 2016-17 and 2017-18 at International Crops Research Institute for the Semi-arid Tropics, Patancheru, Hyderabad to study the influence of tillage practices and residue management practices on yield attributes and yield of maize in maize-based cropping systems under semi-arid tropics. The field experiment was laid out on broad-beds and furrows in a split-split design with four replications under rainfed conditions. Main plot consisted of two tillage practices (minimum tillage and conventional tillage), sub-plot of two crop residue management practices (residue addition and no-residue addition) and sub-sub plot of two cropping systems (Maize-chickpea sequential cropping and maize+pigeonpea intercropping system). The results revealed that yield and yield attributes of maize did not vary significantly due to tillage practices, however, minimum tillage led to considerable yield losses. Among the residue management practices, addition of crop residue recorded significantly higher yield and yield attributes (cob girth, number of grain rows and test weight) as compared to no residue addition. Yield attributes and yield remained non-significant among the two cropping systems.

Rainfed areas in India are spread across varied climate and soil conditions where crop production is constrained by several factors. Conservation agriculture (CA) is often advocated as one of the adaptation and mitigation strategies for the climate change and conservation of natural resources. It comprises of three basic components of minimum tillage, biomass addition and crop rotations with legumes (Hobbs, 2007; Thierfelder *et al.*, 2013) which are considered to play major role for addressing the challenges of decline in soil health and improving crop yield. The current practice of intensive cultivation and declining investment of organic matter into soil has increased the vulnerability in terms of loss of organic matter and nutrients, potentially leading to a loss in fertility (Kautz *et al.*, 2013) through exposing and oxidizing soil organic carbon and ultimately deteriorating soil health and resilience, thereby threatening sustainable production. Therefore, conservation agriculture can play an important role in mitigating climate risk especially in arid and semi-arid regions. However, there are divergent views about the long-term impact of conservation agriculture on crop performance and reclamation of soil health.

Linkages of soil organic matter with soil health and yield are well established and so investments in terms of organic inputs are likely to benefit in sustainable productivity. Incorporation of crop residues alters the soil environment, which in turn influences the microbial population and activity in the soil and subsequent nutrient transformations. It is through this chain of events that management of crop residues regulates the efficiency with which fertilizer, water, and other reserves are used in a cropping system. Competitive usage of crop residue as animal fodder is a major constraint in the model of conservation agriculture (Mazvimavi and Twomlow 2009), where retention of crop residue is a pre-requisite. So, it depends on the choice of crops and in turn the cropping system being practiced which can decide the fate of residue and success of conservation agriculture practice. The hardy stubbles in crops like pigeonpea, maize and others do not find alternate economic uses for the farmers,and are potential biomass for recycling from soil health point of view.

Maize followed by chickpea and maize intercropped with pigeonpea are important cropping systems in the semi-arid tropics in general and in India specifically. These two systems are thus potential opportunities to scale-up conservation agriculture practices of residue and tillage management to the benefit of many smallholders who practice it.

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Table 1. Effect of tillage and residue management practices on cob length (cm) and cob girth (cm) of maize in maize-chickpea and maize+pigeonpea cropping systems

Treatment	Cob length (cm)						Cob girth (cm)					
	2016-17		2017-18		Pooled		2016-17		2017-18		Pooled	
Main plot: Tillage (M)												
Conventional Tillage	16.15		19.39		17.77		4.30		4.33		4.31	
Minimum Tillage	16.16		19.14		17.65		4.26		4.13		4.20	
S.Em ±	0.58		0.70		0.43		0.11		0.11		0.08	
CD (P=0.05)	NS		NS		NS		NS		NS		NS	
Sub plot: Residue management (S)												
No residue addition	15.93		19.43		17.68		4.19		4.11		4.20	
Residue addition	16.39		19.10		17.74		4.37		4.34		4.36	
S.Em ±	0.51		0.45		0.32		0.05		0.07		0.06	
CD (P=0.05)	NS		NS		NS		0.17		0.22		0.18	
Sub-sub plot: Cropping system (C)												
Maize-chickpea	16.27		20.04		18.16		4.19		4.33		4.26	
Maize+pigeonpea	16.05		18.48		17.26		4.36		4.13		4.24	
S.Em ±	0.27		0.39		0.21		0.10		0.13		0.10	
CD (P=0.05)	NS		0.86		0.46		NS		NS		NS	
Interaction	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**
MxS	0.77	NS	0.83	NS	0.53	NS	0.12	NS	0.20	NS	0.11	NS
MxC	0.64	NS	0.80	NS	0.48	NS	0.12	NS	0.18	NS	0.10	NS
SxC	0.58	NS	0.60	NS	0.38	NS	0.15	NS	0.17	NS	0.13	NS
MxSXC	0.86	NS	1.00	NS	0.61	NS	0.20	NS	0.25	NS	0.16	NS

Table 2. Effect of tillage and residue management practices on no. of grain rows and no. of grains per row of maize in maize-chickpea and maize+pigeonpea cropping systems

Treatment	Number of grain rows						Number of grains per row					
	2016-17		2017-18		Pooled		2016-17		2017-18		Pooled	
Main plot: Tillage (M)												
Conventional Tillage	11.88		12.19		12.03		24.19		21.50		22.84	
Minimum Tillage	12.25		12.25		12.25		24.19		20.94		22.56	
S.Em ±	0.22		0.41		0.22		0.66		0.31		0.39	
CD (P=0.05)	NS		NS		NS		NS		NS		NS	
Sub plot: Residue management (S)												
No residue addition	12.31		12.50		12.41		24.06		21.00		22.53	
Residue addition	11.81		11.94		11.88		24.31		21.44		22.88	
S.Em ±	0.11		0.12		0.14		0.36		0.38		0.29	
CD (P=0.05)	0.35		0.38		0.44		NS		NS		NS	
Sub-sub plot: Cropping system (C)												
Maize-chickpea	12.19		12.44		12.31		24.06		21.06		22.56	
Maize+pigeonpea	11.94		12.00		11.97		24.31		21.38		22.84	
S.Em ±	0.29		0.24		0.18		0.50		0.46		0.35	
CD (P=0.05)	NS		NS		NS		NS		NS		NS	
Interaction	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**	**S.Em ±**	**CD (P=0.05)**
MxS	0.35	NS	0.42	NS	0.26	NS	0.76	NS	0.49	NS	0.49	NS
MxC	0.40	NS	0.27	NS	0.22	NS	0.83	NS	0.55	NS	0.53	NS
SxC	0.37	NS	0.47	NS	0.29	NS	0.62	NS	0.60	NS	0.45	NS
MxSXC	0.54	NS	0.56	NS	0.36	NS	1.03	NS	0.81	NS	0.69	NS

The semi-arid zone has the highest prospects for rapid tillage technological package development, because of the crops and cropping systems used and, secondly, because of the urgent need for the development of soil and water conservation and management practices to increase crop production. The experiment was a continuation of a previous experimental set up which started at ICRISAT in 2009. Therefore, the present study entitled "Influence of tillage practices and residue management practices on yield attributes and yield of maize in maize-based cropping systems under semi-arid tropics"was carried out.

MATERIAL AND METHODS

A long-term field experiment was established in *kharif*/rainy (June-Oct) 2009 season at the ICRISAT on-station farm (17.50 ºN, 78.26 ºE and altitude 545 m) near Hyderabad, Telangana state, India. The soil of the experimental site is a Vertisol. During the growth period, a total rainfall of 998.7 mm was received in 56 rainy days during *kharif* 2016-17 and 1108.4 mm in 61 rainy days during *kharif* 2017-18. The field experiment was laid out on broad-beds and furrows (in 1.05 m wide raised bed followed by 0.45 m wide furrow) in a split-split design with four replications under rainfed conditions. Main plot consisted of two tillage practices (minimum tillage and conventional tillage), sub-plot of two crop residue management practices (residue addition and no-residue addition) and sub-sub plot of two cropping systems (Maize-chickpea sequential cropping and maize+pigeonpea intercrop). Soil disturbance in minimum tillage plots was restricted to minor refreshing of furrows before the start of *kharif*/ rainy season, while in conventional tillage plots, ploughing of field with chisel plough, mould board plough and ridge and harrow as normal farmers' practice was undertaken. The residues were removed completely from the no-residue addition treatment plots, while entire crop residues were chopped into finer sizes and spread over the beds after end of the crop season in the residue addition plots. Sowing of crop was done with the help of seed-cum-fertilizer drill. Maize hybrid HTM-5401 was intercropped with pigeonpea hybrid ICPH-2671 in the maize+pigeonpea intercropping system. In maize-chickpea sequential cropping system, maize hybrid HTM-5401 was grown in rotation with chickpea variety ICCV-2. The fertilizer schedule adopted for maize crop was 150, 60 and 40 kg ha^{-1} of N, P and K respectively and for chickpea was 25 and 50 kg ha^{-1} of N and P respectively. Entire dose of phosphorus and potassium were applied as basal in the form of DAP and MOP respectively. Nitrogen in the form of urea after calculating the proportion supplied through DAP was applied in three splits as per schedule i.e., 1/3rd N as basal, 1/3rd N at 30 DAS and remaining 1/3rd N at 60 DAS. Secondary nutrients S in the form of gypsum and micronutrient B in the form of solubor were applied every second year. This study documents the impacts of tillage and residue management during 8th and 9th year of the experiment *i.e*., during 2016-17 and 2017-18 cropping seasons. For yield estimation, destructive samples were taken in an area of 3 x 3 square metre and yields were extrapolated in kg per ha.

At harvest, plant samples from each plot were harvested to record the yield-attributing characteristics, such as cob length, cob girth, number of grain rows, number of grain per row, test weight and grain yield. The data recorded on various parameters of the crop during the course of investigation was statistically analyzed following the analysis of variance for split-split plot design given by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Yield attributes

Tillage and residue management practices did not show any significant influence on the cob length and number of grain rows of maize during both the years of study and pooled means. However, cob length in general was found higher under maize-chickpea cropping sequence and statistically significant during 2017-18 and number of grain rows was significantly higher under residue addition treatments over no residue addition during both the years and pooled means. Significantly higher cob girth was recorded under residue addition treatment over no residue addition during both the years. However, tillage and cropping system did not influence cob girth significantly during both the years and pooled means. No significant difference in number of grains per row was observed in response to tillage, residue management and cropping system during both the years of study and pooled means. 100-seed weight of maize tended to be higher under residue addition practice with statistically higher values during 2016-17 while, tillage and cropping systems did not show any significant influence on the 100-seed weight of maize. Superior yield attributes under addition of residue can

Table 3. Effect of tillage and residue management practices on 100-seed weight (g) of maize in maize-chickpea and maize+pigeonpea cropping systems

Treatment	100-seed weight (g)		
	2016-17	2017-18	Pooled
Main plot: Tillage (M)			
Conventional Tillage	35.04	38.91	36.98
Minimum Tillage	35.16	38.44	36.80
S.Em ±	1.31	0.54	0.59
CD (P=0.05)	NS	NS	NS
Sub plot: Residue management (S)			
No residue addition	36.30	39.14	37.64
Residue addition	33.90	38.21	36.14
S.Em ±	0.90	0.97	0.54
CD (P=0.05)	1.96	NS	1.17
Sub-sub plot: Cropping system (C)			
Maize-chickpea	35.44	38.97	37.29
Maize+pigeonpea	34.76	38.38	36.48
S.Em ±	0.92	0.62	0.71
CD (P=0.05)	NS	NS	NS

Interaction	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
MxS	1.60	NS	1.11	NS	0.92	NS
MxC	1.59	NS	0.82	NS	0.80	NS
SxC	1.28	NS	1.15	NS	0.89	NS
MxSxC	2.04	NS	1.41	NS	1.20	NS

Table 4. Effect of tillage and residue management practices on grain yield (kg ha^{-1}) of maize in maize-chickpea and maize+pigeonpea cropping systems

Treatment	Grain yield (kg ha^{-1})		
	2016-17	2017-18	Pooled
Main plot: Tillage			
Conventional Tillage	5573	4593	5083
Minimum Tillage	5140	4215	4678
S.Em ±	104	334	182
CD (P=0.05)	NS	NS	NS
Sub plot: Residue management			
No residue addition	4813	3956	4384
Residue addition	5901	4856	5379
S.Em ±	294	117	160
CD (P=0.05)	720	286	392

Contd...

Treatment	**Grain yield (kg ha^{-1})**		
	2016-17	**2017-18**	**Pooled**
Sub-sub plot: Cropping system			
Maize-chickpea	5354	4238	4798
Maize+pigeonpea	5359	4570	4912
S.Em ±	334	217	185
CD (P=0.05)	NS	NS	NS

Interaction	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)	S.Em ±	CD (P=0.05)
MxS	312	NS	354	NS	243	NS
MxC	350	NS	398	NS	260	NS
SxC	445	NS	247	NS	245	NS
MxSXC	566	NS	469	NS	357	NS

be attributed to improved growth of plants owing to better physico-chemical conditions of soil which favourably increased the availability of nutrients and moisture and in turn nutrient uptake of plant (Bahar, 2013).Also, significantly higher cob girth led to higher number of grain rows.Superior yield attributes of maize can also be attributed to higher sink capacity of crop in mulched plots confirmed by higher nutrient uptake (Kumar and Angadi, 2016; Bahar, 2013).

Yield

No significant difference was observed in the maize yield in response to tillage practices. However, yields were numerically higher under conventional tillage over minimum tillage treatments. Increase in yield under conventional tillage was 8% and 9% in 2016-17 and 2017-18, respectively.Maize yields were significantly higher under residue addition over no residue addition treatments during both years and pooled means. Increase in yield under residue addition over no residue addition was 23% during both the years.

Maize yields did not differ significantly under two cropping systems each during 2016-17 and 2017-18. However, yield tended to be higher under the maize+pigeonpea cropping system especially during 2017-18.

Yield of maize declined with the minimum tillage due to poor stand establishment owing to a denser top soil (Martínez *et al.*, 2016). Denser top soil also reduces infiltration and consequently low moisture availability in the root zone cause a decline in the yield (Ndoli *et al.*, 2018). Pittelkow *et al.* (2015), in a global meta-analysis also observed a negative yield response to minimum till irrespective of residue addition and crop rotation. Arvidsson *et al.* (2014) also observed an average yield loss of 10% under minimum till conditions in a meta-analysis of large dataset of Swedish field experiments.

The increase in maize yield under residue addition is apparently due to the carbon sequestered and enhanced availability of micro and secondary nutrients. The linkages of soil organic-C with soil physical, chemical and biological properties and yield are well established (Lal, 2013; Ngwira, 2014). With the slow release of additional nutrients through recycled biomass, the yield improvement is on expected lines. Moreover, due to the mulching effect of residue, the evaporation losses are reduced while improving infiltration and conservation of soil moisture (Jat *et al.*, 2015).

As regards the tendency to increase yield under intercropping system might be due to the better resilience building which can be understood by the improved carbon and nutrient status of the soil. Though, yield in general declined during the year 2017-18 as compared to 2016-17 probably due to less rainfall received during grain filling stage in September month, but maize+pigeonpea intercropping systems could effectively plug most of the loss in yield due to huge C-sequestration and improvement in soil health.

This improvement in soil health might be attributed to the huge amount of residue being added to the system for past 9 years and also addition of organic matter in the form of pigeonpea leaf fall over the years.

CONCLUSION

The study revealed that minimum tillage leads to considerable losses of crop yield in comparison to conventional tillage practices as there is a reduction in plant stand due to compaction of top soil layer. Addition of crop residues proved to be beneficial in improving yield attributes and yield by positively influencing soil nutrient availability and carbon concentration.

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EFFECT OF DIFFERENT ESTABLISHMENT METHODS AND NITROGEN LEVELS ON YIELD ATTRIBUTES, YIELD, NUTRIENT UPTAKE AND ECONOMICS OF RICE

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ABSTRACT

A research experiment was conducted on rice during *kharif* 2015-17 at Regional Agricultural Research Station, Warangal (Telangana) under different establishment methods (machine transplanting, conventional transplanting, drum seeding and broadcasting) with three nitrogen levels (120,160 and 200 kg ha^{-1}). Significantly higher number of panicles m^{-2} (317), grains per panicle (277), grain yield (5345 kg ha^{-1}) and straw yield (6305 kg ha^{-1}) were recorded in machine transplanting over other establishment methods. With increase in levels of nitrogen, the yield and yield attributes also showed an increase upto 200 kg N ha^{-1} but found on par with 160 kg N ha^{-1}. The net income (Rs.64,587) as well as B:C ratio (1:3.1) was maximum with machine transplanting closely followed by broadcasting (1:3.0).

Rice is the most important staple food for more than half of the world's population and is a major source of dietary protein for most people in tropical Asia (Juliano, 1993). In India, it is grown in an area of 44 m ha with a production of 107 million tonnes with a productivity of 2.42 t ha^{-1}. In Telangana, rice is cultivated in an area of about 2 m ha with an annual production of 6.62 million tonnes and productivity of 3.29 t ha^{-1} (Statistical year book, 2015). In all rice growing areas there is an acute shortage of human labour during transplanting period due to diversion of labour to non agricultural sectors resulting in delay in transplanting, reduced yield and lesser profit. In the context of acute labour shortage, the traditional method of transplanting becomes rather difficult to ensure timely planting with optimum age of seedlings. To overcome these difficulties traditional method of transplanting can be substituted by sprouted seeding with drum, broadcasting and machine transplanting with young nursery. Among the nutrients nitrogen is the major yield limiting factor in rice cultivars. Hence, precise N application based on crop need helps in improving the yield and reduces the N losses. The optimum use of N can be achieved by supplementing optimum quantity of nitrogen with crop demands as expected to be varied with different establishment methods.

MATERIAL AND METHODS

The experiment was conducted during *kharif* 2015-17 at Rice block in Regional Agricultural Research Station, Warangal (Telangana), located at 18^0 01.077 N latitude 79^0 36.197 E longitudes and an altitude of 259 m above mean sea level. The experiment was conducted to study the effect of different establishment methods and nitrogen levels on yield attributes, yield and economics of rice. A composite soil sample was collected from 0-20 cm depth during the study years, processed and analysed for pH, electrical conductivity, organic carbon, soil available nitrogen, phosphorus, potassium and micronutrients (Zn, Cu, Fe, Mn and Boron) following standard procedures. The experiment was laid out in strip-plot design with 12 treatments replicated three times.

Rice (RNR-15048) nursery was sown during second week of July for conventional transplanting, for machine transplanting nursery was sown in last week of July, for drum seeding and broadcasting seed was soaked for 24 hours and incubated for 24 hours before sowing in the main field and four establishment methods (machine transplanting, conventional transplanting, drum seeding and broad casting) were sown in main field at a time in second week of August. The crop was maintained weed free, pest free and harvested at 125 days after sowing. The grain and straw samples were collected at harvest, oven dried at 70^{0}C processed and analysed for total content of N, P, K, Zn, Cu, Fe and Mn following standard procedures.

The economics were also calculated on the basis of cost of cultivation, gross returns, net returns and benefit cost ratios. The cost of cultivation for each

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treatment was calculated by summing all the variable cost items in the production process. Similarly, gross returns were calculated based on prevailing market price of the produce. The net returns were obtained after deducting the cost of cultivation from gross returns. Thus, the benefit cost analysis was obtained by dividing total returns from a unit with total cost of a unit.

RESULTS AND DISCUSSION

The experimental soil was clay in texture, moderately alkaline in reaction (pH - 8.15), non-saline in nature (EC - 0.44 dSm^{-1}), higher in organic carbon content (OC- 0.88%), medium in available nitrogen (339 kg ha^{-1}), high in available phosphorus (68 kg ha^{-1}), low in available potassium (235 kg ha^{-1}) and Zn, Cu, Fe and Mn (0.66, 1.38, 11.48 and 3.56 mg kg^{-1}, respectively) were marginally available.

Number of effective tillers (panicles)

Significantly higher number of panicles m^{-2} (317) was recorded by machine transplanting over other establishment methods. The increase in yield attributes with machine transplanting was mainly due to optimum plant population, plant geometry (30 cm x 12 cm) coupled with transplanting young seedlings (17 days) that resulted in even distribution of light, moisture and nutrients among rice plants leading to better growth and yield attributes. (Revathi *et al.,* 2016 and Latheef Pasha *et al.*, 2009). Significantly higher number of panicles m^{-2} (288) was recorded with application of 160 kg N ha^{-1} over120 kg N ha^{-1} but at par with 200 kg N ha^{-1}. The increased yield attributes in this treatment was due to favorable root growth and higher mobility of nitrogen in soil solution and its absorption by plant root. This was in conformity with Pramanik *et al.* (2013). Number of panicles m^{-2} was not significantly influenced by interaction effect between establishment methods and nitrogen levels (Table 1).

Panicle length

Significantly, higher panicle length (24.90 cm) was recorded in machine transplanting over other establishment methods. It may be due to lower competition for space, sunlight and nutrients in machine transplanted rice than direct seeding. Similar results were also reported by Mukesh Kumar Pandey *et al.* (2018). However, higher panicle length (24.39 cm) was recorded with application of 160 kg N ha^{-1} over 120 and 200 kg N ha^{-1}. Longer panicle length due to higher nitrogen may be attributed to the role of nitrogen in panicle formation as well as panicle elongation which in turn results in increased panicle length with increase of N-fertilization. This was also reported by Pramanik *et al.* (2013). The interaction effect between establishment methods and nitrogen levels on panicle length were not significant (Table 1).

Number of filled grains

Significantly, higher number of filled grains per panicle (277) was recorded by machine transplanting over other establishment method. This may be due to more light interception because of wider spacing

Table 1. Effect of different establishment methods and nitrogen levels on yield attributes of rice (Pooled)

Establishment methods (A)	Panicles				Panicle length(cm)				Filled grains			
	N-levels (B)(kg ha^{-1})				N-levels (B)(kg ha^{-1})				N-levels (B)(kg ha^{-1})			
	120	160	200	Mean	120	160	200	Mean	120	160	200	Mean
MT	305	329	316	**317**	24.42	25.35	24.92	**24.90**	264	290	278	**277**
CT	263	280	282	**275**	23.89	24.68	24.31	**24.29**	250	277	261	**263**
DS	255	269	269	**264**	23.23	24.02	23.75	**23.67**	243	269	258	**256**
BC	260	272	276	**269**	22.62	23.50	23.02	**23.04**	234	256	248	**246**
Mean	**271**	**288**	**286**		**23.54**	**24.39**	**24.00**		**248**	**273**	**261**	
Factors	**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**	
A	23.00		7.21		0.27		0.08		8.12		2.11	
B	4.00		1.21		0.10		0.03		2.12		1.11	
A X B	NS		12.00		NS		0.14		NS		4.12	
B X A	NS		7.12		NS		0.09		NS		3.11	

MT: Machine Transplanting, CT: Conventional Transplanting, DS: Drum Seeding, BC: Broad Casting

(30x12cm), that resulted in more dry matter accumulation and partitioning into sink (panicles). This was also reported by Revathi *et al.,* (2016) and Latheef Pasha *et al.,* (2009). Significantly, higher number of filled grains per panicle (273) was found by the application of 160 kg N ha^{-1} over the 120 and 200 kg N ha^{-1}. The results indicated that application of low dose of fertilizer did not mitigate the nutrient need of the crop particularly during the grain filling period resulting in lower number of filled grains panicle^{-1}. The results are in conformity with the finding of Pramanik *et al.*,(2013). On the other hand, application of 200 kg N ha$^{"1}$ reduced the number of filled grains panicle^{-1}, which may be due to an increase in competition for metabolic supply among tillers or possibly due to vigorous vegetative growth causing heavy drain on soluble carbohydrate resulting in its reduced availability for spikelet formation and thereby affecting the production of fertile spikelets. Number of filled grains per panicle was not significantly influenced by interaction effect between establishment methods and nitrogen levels (Table 1).

1000 grain weight (Test weight)

The test weight was not significantly influenced by establishment methods and ranged between 11.64 to 12.08 g under different crop establishment method. This was also reported by Latheef Pasha *et al.,* (2009) and Sreenivasulu *et al.,* (2014). Similarly, the test weight was not significantly influenced among different nitrogen levels and ranged between 11.43 to 12.22 g (Table 2). Increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain development. At higher nitrogen level of 200 kg ha^{-1} produced lesser test weight than at 160 kg ha^{-1}. Reduction in 1000-grain weight with increasing levels of N is probably the result of insufficient supply of carbohydrates to individual spikelets due to competition effect resulted by vigorous rice growth and the increased number of its spikelets. This effect further resulted in poor dry matter accumulation in the spikelets of rice Pramanik *et al.,* (2013). Similarly, Hasegawa *et al.*, (1994) also indicated that increased number of spikelets and vigorous growth of rice due to high rates of N fertilizer application induce competition for carbohydrate availability for grain filling and spikelet formation. This was in agreement with the findings of Channabasavanna and Setty (1994) and Raju and Reddy (1993).

Grain yield

Significantly higher grain yield (5345 kg ha^{-1}) was recorded with machine transplanting over the other establishment methods. This is due to better vegetative growth, dry matter accumulation and effective partitioning to the panicles resulting in more number of panicles m^{-2} and grains per panicle in these treatments which has ultimately improved grain yield. The increase in grain yield of rice in machine transplanting was in agreement with the results reported by Revathi *et al.,* (2016). Among different nitrogen levels 160 kg N ha^{-1} recorded significantly higher grain yield (4850 kg ha^{-1}) over 120 kg N ha^{-1} (4412 kg ha^{-1}) but it is at par with 200 kg N ha^{-1} (4702 kg ha^{-1})(Table 2). This could mainly be attributed to the increase in number of panicles m^{-2}, total number of filled grains panicle^{-1} and test weight. Similar results were also reported by Ghanshyam et *al.,* (2015) and Pramanik *et al.,* (2013). Behera (1998) also reported improvement in grain yield is due to improvement in yield attributes. Increase in yield attributes are associated with better nutrition, plant growth and increased nutrient uptake (Kumar and Rao, 1992 and Thakur, 1993).The interaction effect between establishment methods and nitrogen levels on grain yield were not significant.

Straw yield

Significantly higher straw yield (6305 kg ha^{-1}) was recorded by machine transplanting over other systems. Higher dry matter production of the above treatment may be attributed to better establishment of seedlings and more number of tillers per meter square. Similar results were also reported by Sathish *et al.,* (2016). Among different nitrogen levels 200 kg N ha^{-1} recorded significantly higher straw yield (6114 kg ha^{-1}) over 120 and 160 kg N ha^{-1}(Table 2). Similar results were also reported by Ghansham *et al.,* (2015) and Pramanik *et al.,* (2013). Dry matter production was not significantly influenced by interaction effect between establishment methods and nitrogen levels.

Table 2. Effect of different establishment methods and nitrogen levels on test weight, grain and straw yield of rice (Pooled)

Establishment methods (A)	**Test weight (g)**				**Grain yield (kg ha^{-1})**				**Straw yield (kg ha^{-1})**			
	N-levels (B)(kg ha^{-1})				**N-levels (B)(kg ha^{-1})**				**N-levels (B)(kg ha^{-1})**			
	120	**160**	**200**	**Mean**	**120**	**160**	**200**	**Mean**	**120**	**160**	**200**	**Mean**
MT	11.68	12.50	12.07	**12.08**	5059	5579	5397	**5345**	5938	6352	6625	**6305**
CT	11.37	12.38	11.99	**11.91**	4634	5057	4960	**4884**	5460	5868	6299	**5876**
DS	11.31	11.91	11.70	**11.64**	4210	4564	4399	**4391**	4845	5475	5676	**5332**
BC	11.34	12.10	11.78	**11.74**	3744	4199	4050	**3998**	4894	5419	5857	**5390**
Mean	**11.43**	**12.22**	**11.88**		**4412**	**4850**	**4702**		**5284**	**5778**	**6114**	
Factors	**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**	
A	NS		0.12		176		51		373		108	
B	NS		0.05		91		30		155		52	
A X B	NS		0.22		NS		88		NS		187	
B X A	NS		0.16		NS		71		NS		137	

MT: Machine Transplanting, CT: Conventional Transplanting, DS: Drum Seeding, BC: Broad Casting

Total nitrogen uptake

Total nitrogen uptake was found significantly higher in machine transplanting (121 kg ha^{-1}) over other establishment methods (Table 3). This is due to large and functional root system and also higher dry matter production per unit area in machine transplanting and this was in conformity with Revathi *et al.,* (2016) and Sathish *et al.,* (2016). Significantly higher total nitrogen uptake (121 kg ha^{-1}) was recorded by the application of 160 kg N ha^{-1} over the 120 and 200 kg N ha^{-1}. The higher nitrogen uptake with application of 160 kg N ha^{-1} may be directly related to the higher grain and straw yield. These results were in contrast to the findings of Ghansham Payman *et al.,* (2015) where maximum total nitrogen uptake was recorded at 200 kg N ha^{-1} followed by 160 kg N ha^{-1}. The total nitrogen uptake was not significantly influenced by interaction effect between establishment methods and nitrogen levels.

Total phosphorus uptake

Significantly higher Phosphorus uptake was recorded in machine transplanting (21.10 kg ha^{-1}) over drum seeding and broadcasting and was at par with conventional transplanting method (Table 3). This is due to large and functional root system and also higher dry matter production per unit area in machine transplanting over the others and this was in conformity with Revathi *et al.,* (2016) and Sathish *et al.,* (2016).

Among different nitrogen levels, application of 160 kg N ha^{-1} recorded significantly higher P-uptake (19.84 kg ha^{-1}) over the 120 kg N ha^{-1} and it is at par with 200 kg N ha^{-1}. The higher phosphorus uptake with application of 160 kg N ha^{-1} may be directly related to the higher grain and straw yield. Similar results were also reported by Ghansham *et al.,* (2015). The total phosphorus uptake was not significantly influenced by interaction effect between establishment methods and nitrogen levels.

Total potassium uptake

Significantly higher total potassium uptake was recorded by machine transplanting (103 kg ha^{-1}) over drum seeding and broadcasting and was at par with conventional transplanting method (Table 3). This is due to large and functional root system and also higher dry matter production per unit area in machine transplanting over the others and this was in conformity with Revathi *et al.,* (2016) and Sathish *et al.,* (2016). Among different nitrogen levels application of nitrogen @160 kg ha^{-1} recorded significantly higher potassium uptake (98 kg ha^{-1}) over 120 kg N ha^{-1} and it is at par with 200 kg N ha^{-1}. The higher potassium uptake with application of 160 kg N ha^{-1} may have directly related to the higher grain and straw yield. The similar results were also reported by Ghansham *et al*., (2015).The total potassium uptake was not significantly influenced by interaction effect between establishment methods and nitrogen levels.

Table 3. Effect of different establishment methods and nitrogen levels on N, P, K uptake in rice (Pooled)

Establishment methods (A)	N-Uptake (kg ha^{-1})				P-Uptake (kg ha^{-1})				K-Uptake (kg ha^{-1})			
	N-levels (B)(kg ha^{-1})				N-levels (B)(kg ha^{-1})				N-levels (B)(kg ha^{-1})			
	120	**160**	**200**	**Mean**	**120**	**160**	**200**	**Mean**	**120**	**160**	**200**	**Mean**
MT	102	139	122	**121**	20.16	22.80	20.35	**21.10**	98	108	104	**103**
CT	96	124	113	**111**	19.20	21.16	19.96	**20.11**	89	100	95	**95**
DS	92	116	108	**105**	16.85	18.38	17.76	**17.66**	76	92	86	**85**
BC	85	106	99	**97**	14.48	17.03	15.93	**15.81**	73	91	85	**83**
Mean	**94**	**121**	**111**		**17.67**	**19.84**	**18.50**		**84**	**98**	**93**	
Factors	**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**		**CD(P=0.05)**		**SEm±**	
A	9		3		1.10		0.32		9		2.64	
B	5		2		0.98		0.33		4		1.42	
A X B	NS		5		NS		0.55		NS		4.58	
B X A	NS		4		NS		0.62		NS		3.52	

MT: Machine Transplanting, CT: Conventional Transplanting, DS: Drum Seeding, BC: Broad Casting

Economics

Lowest cost of cultivation (Rs.26,450) was recorded with broad casting closely higher (Rs.26,950) was recorded with drum seeding. The cost of cultivation is high in conventional as well as machine transplanting due to nursery raising and more involvement of human labour. The net income (Rs.64,587) as well as return per rupee invested (1:3.1) is maximum with machine transplanting closely followed by broadcasting (1: 30). The higher yield recorded with machine transplanting was the main reason for higher benefit cost ratio though the cost of cultivation was little bit higher than the drum seeding and broadcasting (Table 4).

Table 4. Effect of different establishment methods and nitrogen levels on economics of rice (Pooled)

Establishment methods (A)	Grain Yield (kg ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs.ha^{-1})	Benefit:Cost ratio
MT	6305	29988	94575	64587	1:3.1
CT	5876	32338	88140	55802	1:2.7
DS	5332	26950	79980	53030	1:2.9
BC	5390	26450	80850	54400	1:3.0

MT: Machine Transplanting, CT: Conventional Transplanting, DS: Drum Seeding, BC: Broad Casting

CONCLUSION

It can be concluded from the results that the rice under machine transplanting found improved grain yield over the other establishment methods and also responded to the application of nitrogen up to 160 kg ha^{-1} by giving the good grain and straw yield. Overall rice under machine transplanting with 160 kg N ha^{-1} proved to be better over others.

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Research Article
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DEVELOPMENT AND EVALUATION OF QUICK COOKING REDGRAM DHAL (*CAJANUS CAJAN* L.)

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ABSTRACT

Four different treatments (T1 and T2 treatments included soaking in 1% hot and cold NaCl solutions;T3 and T4 treatments included soaking, autoclaving, cooling, freezing and dehydrating redgram dhal) were standardized for development of quick cooking dhal. Protein, ash, carbohydrate and energy content were highest in T3 and T4 treatments. Cooking time was lowest in T3 (7 minutes) followed by T4 (6 minutes) treatments as compared to T1, T2 and control samples. Water absorption was also highest in T3 and T4 treatments indicating good volume expansion of dhal. Solids dispersed were lower in T3 and T4 treatments as compared to control red gram dhal. The colour values of T3 and T4 quick cooking dhal treatments were also at par with the control samples indicating good visual appeal of the dhal.

Pulses play an indispensable role in our daily menus serving as the cheapest source of protein, balancing the lysine deficient cereal diets (Bongirwar and Srinivasan, 1971, *Ghadge et al.,* 2008). Red gram (pigeon pea), black gram, pigeonpea, green gram, pea etc. are the main legume crops grown in India, with pigeon pea (*Cajanus cajan* L.) occupying the second largest legume crop grown in India. Pigeonpea is consumed in dehusked split form, commonly called as Redgram dhal, arhar, tur dhal which belongs to family *Leguminosae*. (Nayak and Samuel., 2015).

Pigeonpea (*Cajanus cajan*) is traditionally processed into consumable forms by methods which can be broadly divided into two categories: primary processing (or dehulling) to form dhal and secondary processing that involves cooking, germination and fermentation. India is the largest producer (81.49%) and consumer of pigeonpea in the world (Ghadge et al. 2008) and almost all pigeonpea is milled to produce dhal (Faris and Singh 1990). Out of 14.5 million tons of pulses, nearly 11 million tons are converted to dhal in India for consumption (Jain and Doharey 2009).

The cooking quality of pigeonpea is primarily assessed by its cooking time. With increased urbanization and more women joining the workforce, there is a need to develop products that need less preparation time in households (Shruti *et al*., 2014). Since pigeonpea requires considerable cooking time about 32–68 min (Narasimha and Desikachar 1978), there is a need to have quick cooking red gram dhal (QCRGD). Foods like QCRGD will also be suitable as operational pack rations of armed forces because of their light weight, easy cooking characteristics and long shelf life. Greater emphasis is being given for marketing new products of legumes such as quick cooking dhal or instant dhals which have good market potential as convenience foods (Singh, 2007). Taking this into consideration present investigation was carried out with the objective to develop quick cooking dhal from pigeon pea and to evaluate it for changes in cooking quality and nutritional attributes.

MATERIAL AND METHODS

Red gram dhal was obtained from local grain market. Sample was cleaned properly and utilized for further purpose. Four methods were utilized for development of Quick Cooking Dhal.

Preparation of QCRGD

Treatment 1: *Dhal* was pretreated by soaking redgram dhal in a solution of sodium chloride (1.0%) for 2 h at ambient temperature. After soaking the excess solution was drained and samples were dried in a tray drier at 50°C for an hour till moisture content of 25–30% (Shruti *et al*., 2014).

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Treatment 2: *Dhal* was pretreated by soaking redgram dhal in a solution of sodium chloride (1.0%) for 2 h at 55°C temperature. After soaking the excess solution was drained and samples were dried in a tray drier at 50°C for an hour till moisture content of 25–30% (Modified method from Treatment 1).

Treatment 3: The sound, cleaned red gram dhal was soaked at ambient temperature for 10 h, after which the excess water was removed. The soaked dhal was autoclaved at 15psi pressure for 15 min, and cooled to room temperature. The cooled dhal was subjected to freezing at -24°C for about 3 h followed by drying of frozen redgram dhal in cabinet dryer at 65°C for 3 ½ h. The prepared dried instant dhal was packed in polythene bags by adding some spices (Ghadge *et al.*, 2008).

Treatment 4: The sound, cleaned red gram dhal was soaked at ambient temperature for 8 h, after which the excess water was removed. The soaked dhal was autoclaved at 15psi pressure for 15 min, and cooled to room temperature. The cooled dhal was subjected to freezing at -24°C for about 3 h followed by drying of frozen redgram dhal in cabinet dryer at 65°C for 3 ½ h. The prepared dried instant dhal was packed in polythene bags by adding some spices (Modified method from Treatment 3).

All the four treatments along with a control sample were analysed for the following parameters.

Nutrient content: Moisture content of 10g of control and QCRGD treatments was determined by hot air oven method (IS 1155, IS 4333, 2012). Proximate composition was determined in the finely ground flour obtained from the quick cooking dhal. Ash, protein, fat and crude fiber were determined by AOAC methods (2016). Fat was estimated by soxhlet extraction with petroleum ether (60– 80°C).

Cooking time: Cooking time was determined by cooking the dhal in distilled water until it softened to uniform mass, when pressed between the thumb and forefinger as described by Singh *et al.*, (1984). Dhal sample (10 g) was boiled in 50 mL distilled water. During boiling, samples were removed at 1 min intervals and examined for softness. The time taken to achieve the desirable softness was recorded as the cooking time of the sample. All the samples were also analyzed for cooking time using microwave oven.

Water absorption: Five gram of dhal was taken in a digestion tube and boiled in excess distilled water (35 mL) for 25 min. The excess water, after boiling, was decanted and the dhal was weighed. The amount of water taken up by the dhal was calculated and the results are expressed as per cent water absorption (Singh *et al.*, 1984).

Solids dispersed: The percentage of solids dispersed into the cooking water was determined by the method described by Singh *et al.*, (1984). 5 g dhal was boiled for 25 min and the material was passed through a sieve and residue was washed thoroughly with distilled water. After washing, the residue was dried at 100°C for 3 h. The loss in weight of dhal after boiling was calculated as per cent solids dispersed into the cooking water.

Colour : Colour attributes of the dhal treatments along with control sample was performed by spectrocolorimeter (Hunter labColorflex, Firmware versions 1.1, Reston, Virginia) with a measuring aperture of 36 mm (AOAC 1998). Calibration was accomplished prior to each trial with manufacturer supplied white, green and black tiles. A circular glass cuvette was used to contain the dhal samples for measurement. Sample was placed on the reading lens, and tested. A mean of 3 readings of the sample, produced values of L* (lightness), a* (redness), and b*(yellowness).

Amino Acids : Amino acid profiles in the five RTE extruded samples (unspiced) was determined using the HPLC method (Agilent 1260 Infinity HPLC system, equipped with a ì-degasser, binary pump, standard autosampler, thermostated column compartment, diode array and multiple wavelength detector) after samples were hydrolyzed with 6N HCl (AOAC, 2016). The hydrolysed peptide samples were derivatised with OPA (o-phthalaldehyde for primary amino acids) and FMOC (9- fluorenylmethyl chloroformate (FMOC) for secondary amino acids and analyzed for amino acid composition by a Zorbax Eclipse-AAA column (250 mm x 4.6 mm, L x ID) particle size 5ìm) (Agilent Technologies, Santa Clara, CA). The amino acid composition was expressed as percentage amino acid of total protein content of each sample.

Statistical analysis: Mean and standard deviation for two parallel replicates were calculated. Statistical analysis software SPSS for Windows 10.0 was used for the analysis of data.

RESULTS AND DISCUSSION

The moisture content of control and experimental samples is given in Table.1. The results indicate that, moisture content in the T3 and T4 treatments were lowest compared to control and Nacl treated samples, indicating that storability of T3 and T4 samples would be higher than other samples. Ash content of all the samples ranged between 2.79 g% to 4.35 g%. Higher ash content in the Nacl treated samples could be due to residual effect of the salt used as a pretreatment. Protein, fat and fiber content in all the sample ranged between 21.21 g% – 22.44 g%; 1.78 – 2.81 g% and 3.08 – 4.02 g% respectively. Not much change was observed among the treatments and control samples. The carbohydrates content in control and QCRGD samples ranged between 60.92g% – 66.85g%, while the energy content ranged between 352.88 – 375.27 kcal/100gms. Similar results were reported by Shruti *et al.*, (2014) and Nayak and Samuel (2015).

Table 2. Cooking quality of control and Quick cooking Redgram dhal treatments

QCRGD	Water Absorption (ml/100g)	Solids dispersed (%)
Control	29.74	23.06
T1	116.40	20.69
T2	108.66	12.76
T3	163.39	15.72
T4	149.88	15.57

From consumer's point of view, the cooking quality is also judged to some extent on increase in volume after cooking, higher dispersability of solids into cooking media and improved texture after cooking. The water absorption was least in control sample (29.74 ml/100g) compared to 163.39 ml/100g and 149.88 ml/100gms. It was observed that higher water uptake was inversely proportion to solids dispersed. Solids dispersed ranged between 12.76% to 23.06% in all the samples. The present findings are in agreement to the results obtained by earlier workers Manimekalai *et al.*, (1979) and Singh *et al.*, (1984), wherein the amount of solids dispersed in cooking water and water uptake were negatively correlated with cooking time. In case of dhals, it is the water absorbing capacity and solids dispersed (%) that makes the difference in cooking time. The water absorbing capacity depends on cell wall structure, composition of seed and compactness of the cells in the seed (Rosaiah *et al.*, 1993).

Table 1. Nutrient content of control Redgram dhal and Quickcooking Redgram dhal treatments

Redgram	Moisture (g%)	Ash (g%)	Protein (g%)	Fat (g%)	Fiber (g%)	CHO (g%)	Energy (kCal/100g)
Control	8.88±0.08	3.69±0.04	22.25±0.11	1.78±0.03	3.44±0.58	63.41±0.02	358.64±0.62
T1	9.48±0.03	3.98±0.01	21.21±0.11	2.81±0.42	3.17±0.04	62.53±0.57	360.23±1.98
T2	10.73±0.03	4.35±0.04	21.36±0.11	2.64±0.61	3.47±0.11	60.92±0.74	352.88±2.98
T3	7.71±0.06	2.79±0.01	22.44±0.64	2.48±0.43	4.02±0.06	64.59±0.16	370.40±1.96
T4	6.10±0.08	2.97±0.04	21.77±0.17	2.31±0.38	3.08±0.03	66.85±0.68	375.27±1.40

All values are expressed as Mean ± SD

The cooking quality of dhal is a function of the duration of cooking i.e., the time required to attain desired softness, amount of water absorbed, solids dispersed and texture of the cooked dhal. Results of cooking quality are presented in Table.2 and Fig.1. It was observed that there was a considerable reduction in cooking time of the QCRGD treatments. Lowest cooking time was observed in T3 and T4 treatments with 14 min and 11min in conventional cooking method and 7 min and 6 min respectively in microwave cooking time, compared to control samples. This finding is in agreement with the observations of Shruti *et al.*, (2014), Singh *et al.*, (2003), Gulati *et al.*, (1997) and Vimla and Pushpamma (1987).

Colour of the cooked dhal samples is an important attribute to the consumer and results are presented in Table.3. The values for L* range from

0 - 100, representing black to perfect white,respectively. The L* values of the raw, conventional cooked and microwave cooked samples ranged between 95.83 – 96.70 indicating brightness of the dhal samples.The results of a* values were higher in T3 and T4 compared to other samples indicating lightness in colour. The results of b* were lower in control, T3 and T4 indicating yellowness in the samples, which are more appealing to the consumer.The b* values in T1 and T2 indicated darkness in the sample indicating poor visual appearance, which could be due to effect of Nacl treatment.

Results of amino acids are presented in fig. 2. The results of amino acid composition indicate that, among the essential amino acids, lysine was highest in all the treatments, followed by histidine, isoleucine, phenylalanine and leucine. Tiwari and Singh (2012) reported that pulses contain limiting amount of essential amino acids such as methionine, tryptophan and cystine. Among the non essential amino acids, glutamate, tyrosine, glycine and alanine were predominantly present. There was no considerable change in the amino acids composition among the treatments. Peace et al. (2006) studied the protein

Table 3. Colour studies of control Redgram dhal and Quick cooking Redgram dhal treatments

QCRGD	Raw Redgram				Cooked (Water Bath) sample				Microwave Cooked samples			
	L*	a*	b*	DE*	L*	a*	b*	DE*	L*	a*	b*	DE*
Control	95.98±0.02	-0.55±0.00	-12.98±0.01	14.24±0.01	96.18±0.00	-1.23±0.01	-13.63±0.02	14.93±0.03	96.22±0.00	-1.41±0.01	-13.77±0.01	15.04±0.01
T1	96.58±0.00	-0.55±0.00	-14.51±0.01	15.83±0.01	96.50±0.00	-0.96±0.00	-14.32±0.01	15.63±0.01	96.62±0.01	-0.92±0.01	-14.46±0.02	15.83±0.02
T2	96.70±0.00	-0.45±0.01	-14.83±0.01	16.17±0.00	96.55±0.01	-0.87±0.00	-14.41±0.01	15.73±0.01	96.57±0.00	-0.88±0.00	-14.48±0.01	15.80±0.01
T3	95.83±0.00	-1.34±0.01	-12.83±0.01	14.04±0.01	96.03±0.01	-1.44±0.01	-13.31±0.01	14.54±0.01	96.08±0.00	-1.34±0.01	-12.99±0.01	14.25±0.01
T4	96.25±0.01	-0.85±0.01	-14.55±0.01	15.8±0.01	96.08±0.01	-1.41±0.01	-13.4±0.01	14.65±0.01	96.08±0.01	-1.41±0.01	-13.27±0.01	14.55±0.02

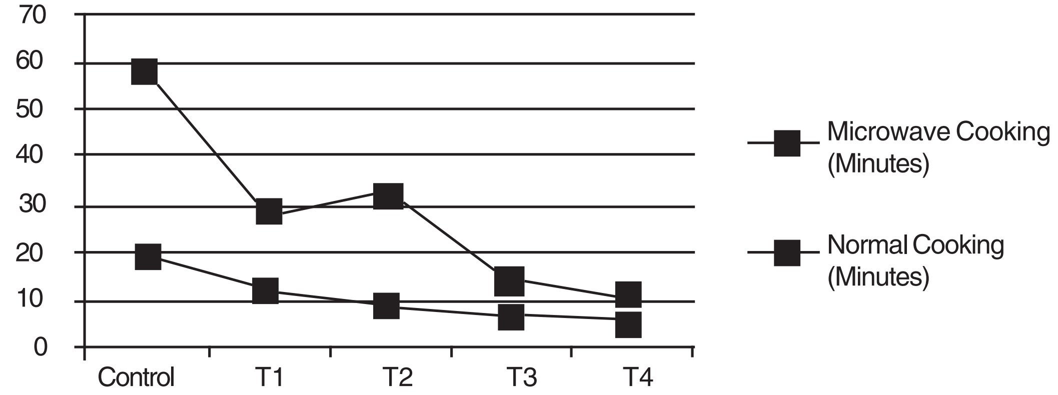

Fig 1: Cooking Time (Minutes) of Quick cooking Redgram dhal

Area % Report of Amino Acids composition in Redgram dhal Control Sample

Date : E:\TP Amino Acids2019 Redgram dhal -ontrol.rslt\Redgram dhal -ontrol.dat
Method : C:\Method\AMN0221216.net
Acquired : 2/26/2019 7:36:54 AM(GMT +05:30)
Printed : 2/28/2019 2:47:36PM (GMT +05:30)

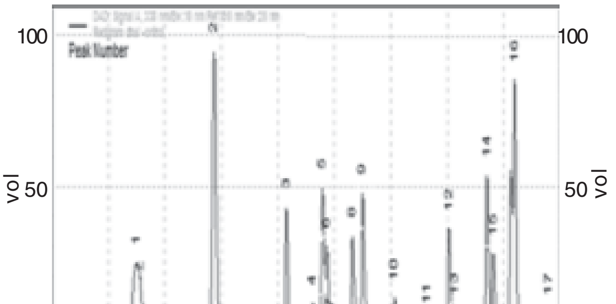

Fig 2a : Amino Acid composition of Control and QCRGD treatments

Area % Report of Amino Acids composition in Redgram dhal T1

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Method : C:\Method\AMN0221216.net
Acquired : 12/24/2018 10:56:19 AM(GMT +05:30)
Printed : 1/21/2019 12:39:56 PM (GMT +05:30)

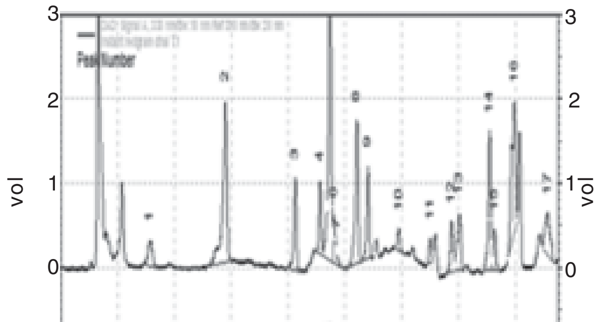

Fig 2b: T1. Instant Redgram Dhal with 1% Nacl treatment in cold water solution

Area % Report of Amino Acids composition in Redgram dhal T2

Date : C:\Result\HPLC-DAD (Offline).35 2019-02-28 20-22-46(GMT+05.30).rslt\Instant redgram dhal T2.dat
Method : C:\Method\AMN0221216.net
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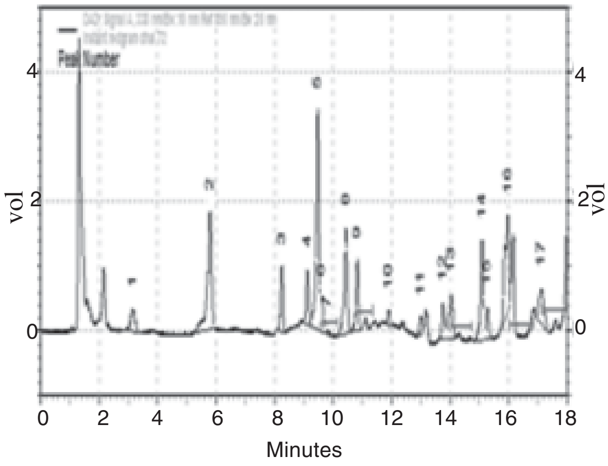

Fig 2c: T2. Instant Redgram Dhal with 1% Nacl treatment in hot water solution

Area % Report of Amino Acids composition in Redgram dhal T3

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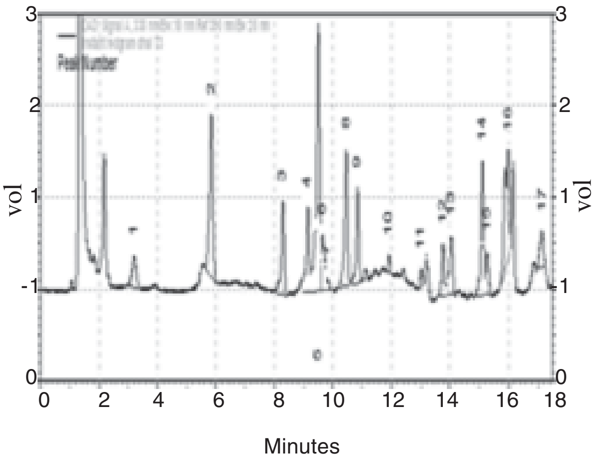

Fig 2d: T3. Instant Redgram Dhal with 10 Hrs soaking followed by Freezing

Area % Report of Amino Acids composition in Redgram dhal T4

Date : C:\Result\HPLC-DAD (Offline).35 2019-01-21 16-16-54(GMT+05.30).rslt\Instant redgram dhal T4.dat
Method : C:\Method\AMN0221216.net
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Printed : 1/21/2019 4:17:54 PM (GMT +05:30)

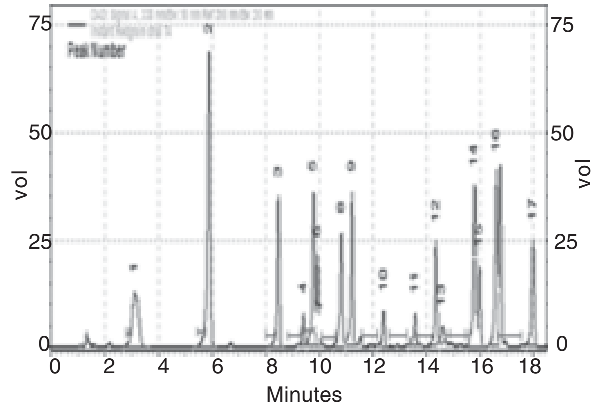

Fig 2e: T4. Instant Redgram Dhal with 8 Hrs soaking followed by Freezing

CONCLUSION

On the basis of results obtained it can be concluded that, cooking time of the dhal can be decreased by giving various pretreatments with either salt solution followed by dehydration or soaking followed by autoclaving, freezing and dehydration. The quick cooking dhal thus developed showed appreciable decrease in cooking time and no significant loss of nutritional value was observed. However, treatment of soaking, autoclaving, freezing and dehydration was superior to NaCl treatments. Although the results are based on the analysis of market sample, it is evident that treatment like soaking, autoclaving, freezing and dehydration is effective in reducing the cooking time of redgram dhal.

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Research Note
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GENETIC ANALYSIS OF TRANSGRESSIVE SEGREGATION IN BACKCROSS DERIVED INTROGRESSION POPULATION OF *ORYZA SATIVA* CV. SAMBA MAHSURI / *O. RUFIPOGON* FOR YIELD ENHANCING TRAITS

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Rice (*Oryza sativa* L.) is a major cereal food crop and consumed by nearly half of the world's population. It constitutes for 35 - 75% of caloric uptake by Asians and planted over 11% of global arable land (Khush, 2005). Because of its agricultural importance, rice has been bred intensively resulting in the doubling of the production by adopting high-yielding varieties/ hybrids. However, this achievement has led to the narrowing of the available genetic base in elite germplasm and is causing much concern about the reduced genetic gain in present day rice breeding. In a genetic diversity study, Sun *et al*., (2001) reported that cultivated rice has only 60% of the alleles of wild rice. A large amount of genetic variation in the genus *Oryza* lies unexploited in wild progenitors (Wang *et al*., 1992). Hence, attention is being shifted to map yield-enhancing QTLs and enrich the cultivated gene pool by introgression of favorable genes/gene complexes from wild species (Tanksley and McCouch, 1997; Swamy and Sarla, 2008). The potential of wild relatives to increase the genetic variability in cultivated rice is becoming increasingly obvious (Vaughan, 1994). The increased variability occurs both by introduction of the pre-existing alleles of wild species and also a lot of genetic variability is created *de novo* (Wang *et al*., 2005; Wang *et al*., 2010).

Oryza rufipogon, a wild species of the genus *Oryza*, also known as *O. perennis*, or *O. balunga*, is a diploid, aquatic plant. It has adaptable habit, erect and lax panicles that stand narrow and oblique, and beaked spikelets with awns (Sarkar *et al*., 2017). Following the identification of yield QTLs yld 1.1 and yld 2.1 from Malaysian accession of *O. rufipogon*, each of which could help increase yield by about 18% (Xiao *et al*., 1996), many researchers exploited the wild species, *O. rufipogon* (Fu *et al*., 2010; He *et al*., 2006; Marri *et al*., 2005; Moncada *et al*., 2001), for yield and grain quality traits. Recognizing the potential of wild species and to discover the unexplored variability in *O. rufipogon*, we generated an advanced backcross populations derived from *O. sativa* Samba mahsuri / *O. rufipogon* (Acc. 8030) comprising 120 BC_2F_1 progenies (Introgression lines) and were evaluated for six yield and yield-related traits.

The study was conducted at ICAR-Indian Institute of Rice Research, Hyderabad. Source of plant materials including seeds of Samba Mahsuri and 120 BC_2F_1 progenies were received from ICAR-IIRR, Hyderabad. Samba mahsuri, a popular variety with medium slender grain with excellent cooking qualities, was used as female parent in inter-specific cross with *O. rufipogon* accession, a progenitor of cultivated rice as the male parent.

F_1 plants produced from the cross Samba mahsuri / *O. rufipogon* were selected based on phenotype. The F_1s were backcrossed to Samba mahsuri, recurrent parent (RP) to derive BC_2F_1 plants. In the BC_1F_1 generation plants with seed dormancy, sterility, and weedy characters were rejected and plants with maximum recovery of characters of recurrent parent were used to backcross with the recurrent parent to obtain BC_2F_1 populations.

The BC_2F_1 population consisting of 120 lines was evaluated in augmented block design during the *Kharif* season of 2017 along with 4 checks namely Samba mahsuri, RNR15048, IR64 and Swarna. Population was grown in single row of 3.0 m in augmented design with spacing of 20 x 15 cm. Recommended agronomic practices were followed to

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raise a good crop in good condition. Observations were recorded for six quantitative traits *viz*., days to flowering (DFF), plant height (PH), Number of tillers per plant (NT), productive tillers/plant (PT), panicle length (PL) (cm) and grain yield / plant (YPP) (g).

The analysis of variance (ANOVA) was carried out as suggested by Panse and Sukhatme (1967). In the present study, transgressive segregants were identified by finding the number of plants exceeding mean value of the better parent or lagging behind the mean value of the poor parent.

The ANOVA revealed significant differences among all the traits *viz*., days to 50 per cent flowering, plant height (cm), number of tillers per plant, productive tillers/plant, panicle length (cm), grain yield per plant (g), indicating the presence of considerable genetic variability among the experimental material under study (Table. 1).

Transgressive segregation produces hybrid progeny phenotypes that are superior to the parental phenotypes. Such plants are produced by accumulation of favourable genes from both the parents as a consequence of segregation and recombination. Unlike heterosis, extreme phenotypes caused by transgressive segregation are heritably stable. Kshirsagar *et al*., 2013 suggested that transgressive segregation can be exploited for development of genotypes with positive characters from both the parents. Transgressive segregants for yield and its component traits in BC_2F_1 population of the crosses Samba mahsuri / *O. rufipogon* was presented in Table 2.

Table 1. Analysis of variance for yield and yield attributing traits

Source of variation	d.f	DFF	PH	NT	PT	PL	YPP
Blocks (Eliminating check+Gen.)	3	0.56	0.01	0.01	0.01	0.022	0.02
Entries(Ignoring blocks)	123	72.17 ***	248.87***	31.36***	31.07 ***	6.37***	38.50***
Checks	3	221.63 ***	550.33***	3.66***	3.67 ***	7.15***	19.67***
Genotypes	119	42.38 ***	236.34***	30.25***	29.94 ***	6.00***	34.40***
Checks vs. Genotypes	1	3171.17 ***	835.76***	246.07***	249.03 ***	48.12***	584.05***
Error	9	1.22	0.01	0.02	0.01	0.01	0.02

, ** and- significant @5%, 1% and 0.1% DFF-Days to 50% flowering, PH-Plant height (cm), NT-Number of tillers/ plant, PT-Productive tillers per plant, PL-Panicle length (cm), YPP-Yield per plant (g)**

Table 2. Transgressive segregants for yield and its component traits in BC2F1 population of the cross between Samba mahsuri/*O. rufipogon*

Traits	BC2F1 Generation of Samba mahsuri X *O. rufipogon* cross				Recurrent Parent (Samba mahsuri)	No. of Transgressive Segregants	
	No. of plants	MEAN	MIN	MAX	Mean	Higher than Recurrent Parent	Lower Than Recurrent Parent
DFF	120	103.45	90.00	127.00	123.50	2	118
PH	120	91.06	61.00	122.00	91.00	55	65
NT	120	13.08	3.00	34.00	16.00	30	90
PT	120	13.05	3.00	34.00	16.00	30	90
PL	120	21.23	15.00	28.00	21.50	52	68
YPP	120	18.32	9.14	39.06	23.50	26	94

DFF-Days to 50% flowering, PH-Plant height (cm), NT-Number of tillers/plant, PT-Productive tillers per plant, PL-Panicle length (cm), YPP-Yield per plant (g)

Wide range of phenotypes were observed for all the characters in the BC_2F_1 population. This clearly suggests that all the traits were governed by many genes and alleles governing these traits seem to act in additive manner showing polygenic inheritance. In the present study high variability is reported for all the traits. This new variability is contributed by alleles of donor parent *O. rufipogon*. Similar results were reported by Moncada *et al*., 2001; Marri *et al*., 2005; Fu *et al*., 2010.

Introgression populations that surpassed the parental limits were observed for for all the traits *viz.,* days to 50 per cent flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, grain yield per plant. This clearly indicates that the parents had different alleles and genes governing yield and its component traits. Hence, there is a lot of scope to bring in beneficial alleles into a single genotype through rigorous selection in later generations for yield and yield attributes. High frequency of favourable transgressive segregants was observed for days to 50% flowering, plant height and panicle length. Transgressive segregants with lower value than recurrent parent were high in number of tillers per plant, number of productive tillers per plant and grain yield per plant. Occurrence of such transgressions is possibly due to accumulation of complementary alleles from both the parents at multiple loci in certain BC_2F_1 population (Tanksley, 1997) and unmasking of recessive deleterious alleles due to inbreeding (Rick and Smith 1953).

Polygenic inheritance and high frequencies of favourable transgressive segregants for yield and its component traits indicated that there is a lot of scope to bring in beneficial alleles from wild species into cultivated rice through careful selection in later generations and identification of plants with many desirable traits which are likely to contribute.

Table 3. Mean performance of BC2F1 population of the cross between Samba mahsuri/*O. rufipogon*

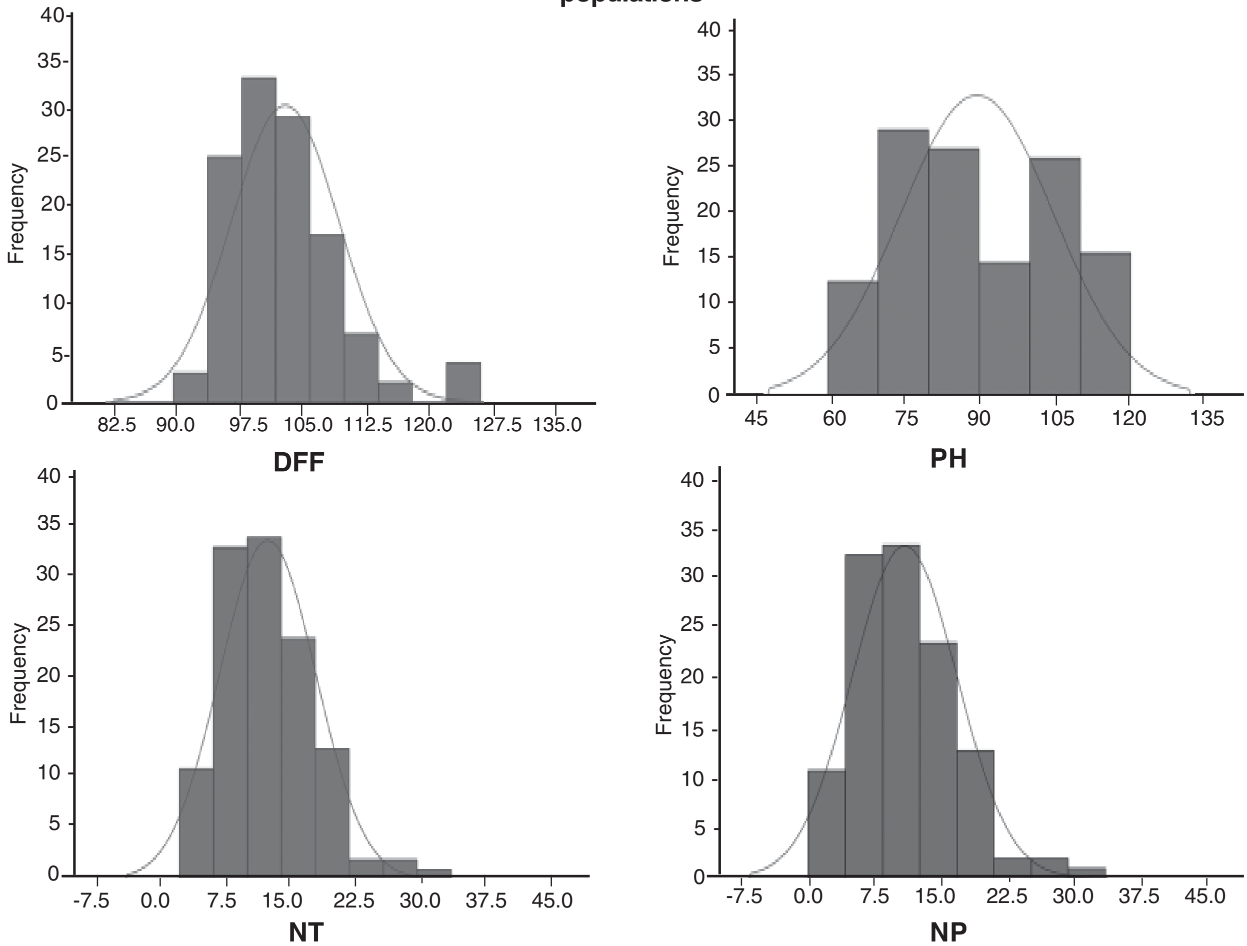
LINES	DFF	PH	NT	NP	PL	YPP
172031-1	105.00	109.50	9.00	9.00	23.00	21.50
172031-2	108.00	116.00	16.00	15.00	22.00	22.50
172031-3	108.00	106.00	20.00	20.00	21.00	27.50
172031-4	108.00	74.00	16.00	16.00	20.00	25.50
172031-5	108.00	67.00	26.00	26.00	15.00	13.35
172031-6	108.00	61.00	8.00	8.00	16.00	14.32
172031-7	113.00	77.00	17.00	17.00	21.00	16.61
172031-8	110.00	97.00	16.00	16.00	19.00	13.49
172031-9	113.00	89.50	18.00	18.00	19.50	14.44
172031-10	112.00	100.00	14.00	14.00	20.00	20.81
172031-11	112.00	95.50	11.00	11.00	20.50	12.70
172031-12	109.00	92.50	22.00	22.00	19.00	14.25
172031-13	113.00	84.00	14.00	14.00	20.50	14.11
172031-14	100.00	115.00	34.00	34.00	23.00	14.04
172031-15	105.00	82.00	20.00	20.00	20.00	14.81
172031-16	107.00	76.00	12.00	12.00	22.00	16.13
172031-17	105.00	70.00	8.00	8.00	20.00	13.58
172031-18	105.00	71.00	11.00	11.00	21.00	17.97
172031-19	106.00	88.00	8.00	8.00	22.50	16.17
172031-20	105.00	81.00	27.00	27.00	21.50	18.53
172031-21	106.00	79.00	17.00	17.00	20.00	13.13
172031-22	95.00	75.00	14.00	14.00	20.00	20.20
172031-23	106.00	76.00	16.00	16.00	17.00	20.06

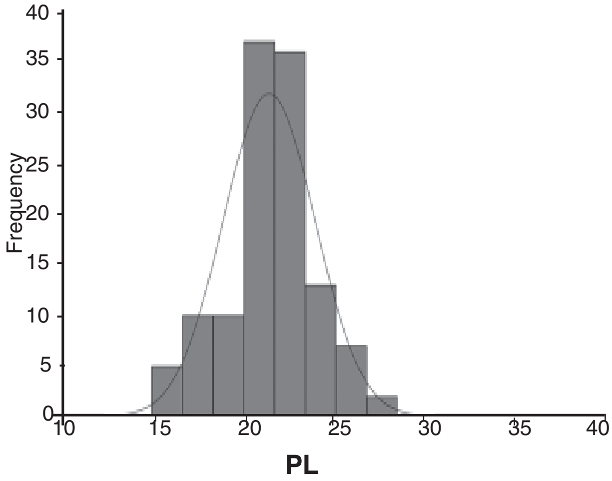
LINES	DFF	PH	NT	NP	PL	YPP
172031-24	98.00	68.00	3.00	3.00	21.50	18.74
172031-25	99.00	80.00	10.00	10.00	22.00	25.18
172031-26	97.00	89.00	9.00	9.00	18.00	17.30
172031-27	98.00	84.00	20.00	20.00	20.00	13.36
172031-28	110.00	78.00	11.00	11.00	19.00	12.30
172031-29	105.00	84.00	11.00	11.00	23.00	17.26
172031-30	110.00	86.00	22.00	22.00	23.50	17.74
172031-31	100.00	78.00	11.00	11.00	21.00	24.88
172031-32	98.00	82.00	18.00	18.00	22.00	27.00
172031-33	99.00	83.00	16.00	16.00	21.00	28.32
172031-34	97.00	112.00	20.00	20.00	23.00	10.93
172031-35	104.00	100.00	8.00	8.00	22.50	11.31
172031-36	98.00	87.00	15.00	15.00	19.00	13.00
172031-37	108.00	80.00	12.00	12.00	20.40	18.08
172031-38	108.00	68.00	15.00	15.00	17.00	14.46
172031-39	97.00	105.00	20.00	20.00	24.00	14.13
172031-40	99.00	65.00	6.00	6.00	16.50	13.32
172031-41	101.00	85.00	12.00	12.00	22.10	13.12
172031-42	110.00	103.00	16.00	16.00	24.00	15.95
172031-43	99.00	105.00	8.00	8.00	20.50	10.17
172031-44	97.00	84.50	18.00	18.00	21.50	12.59
172031-45	100.00	79.00	9.00	9.00	21.10	13.83
172031-46	101.00	88.00	18.00	18.00	23.00	14.85
172031-47	100.00	83.00	14.00	14.00	19.00	19.06
172031-48	101.00	100.00	19.00	19.00	22.00	9.14
172031-49	123.00	98.00	24.00	24.00	21.00	15.38
172031-50	127.00	110.00	8.00	8.00	21.50	11.71
172031-51	115.00	117.00	10.00	10.00	20.50	16.35
172031-52	113.00	112.00	17.00	17.00	21.50	13.52
172031-53	101.00	78.00	14.00	14.00	21.10	20.50
172031-54	102.00	118.00	7.00	7.00	23.50	23.50
172031-55	99.00	112.00	12.00	12.00	20.50	26.45
172031-56	104.00	106.00	6.00	6.00	22.50	25.50
172031-57	104.00	103.00	9.00	9.00	21.20	15.89
172031-58	100.00	100.00	19.00	19.00	22.50	16.91
172031-59	108.00	95.00	11.00	11.00	22.00	18.79
172031-60	100.00	68.00	5.00	5.00	17.00	22.23
172031-61	100.00	73.00	20.00	20.00	22.00	13.01
172031-62	106.00	67.00	3.00	3.00	17.00	11.72
172031-63	109.00	102.00	13.00	13.00	20.00	15.47
172031-64	107.00	106.00	16.00	16.00	20.00	17.05
172031-65	106.00	71.00	14.00	14.00	19.00	14.48

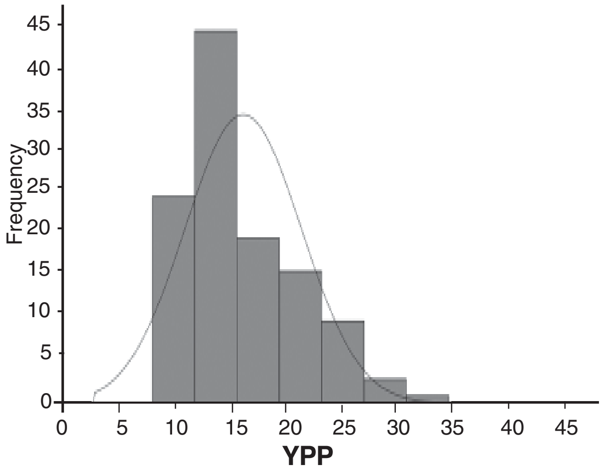
LINES	DFF	PH	NT	NP	PL	YPP
172031-66	96.00	105.00	11.00	11.00	24.00	20.50
172031-67	98.00	98.00	13.00	13.00	19.00	23.03
172031-68	97.00	105.00	12.00	12.00	20.00	34.33
172031-69	98.00	100.00	12.00	12.00	22.00	23.28
172031-70	98.00	116.00	22.00	22.00	23.00	31.73
172031-71	98.00	110.00	11.00	11.00	26.00	23.53
172031-72	98.00	105.00	18.00	18.00	24.00	13.70
172031-73	90.00	83.00	27.00	27.00	25.00	25.20
172031-74	90.00	67.00	5.00	5.00	18.00	12.71
172031-75	91.00	84.00	7.00	7.00	22.00	14.15
172031-76	101.00	77.00	17.00	17.00	26.00	12.11
172031-77	101.00	77.00	6.00	6.00	27.00	15.36
172031-78	99.00	84.00	7.00	7.00	25.00	28.55
172031-79	100.00	86.00	9.00	9.00	19.00	11.32
172031-80	100.00	90.00	11.00	11.00	28.00	39.06
172031-81	100.00	88.00	10.00	10.00	24.50	19.25
172031-82	100.00	93.00	16.00	16.00	22.00	28.06
172031-83	107.00	92.00	7.00	7.00	21.00	17.10
172031-84	103.00	88.00	15.00	15.00	24.00	27.87
172031-85	102.00	80.00	11.00	11.00	22.00	16.48
172031-86	98.00	89.00	18.00	18.00	24.00	15.31
172031-87	98.00	95.00	12.00	12.00	21.00	17.08
172031-88	104.00	103.00	8.00	8.00	23.00	15.45
172031-89	104.00	80.00	15.00	15.00	21.00	14.41
172031-90	97.00	77.00	14.00	14.00	21.90	13.06
172031-91	97.00	69.00	22.00	20.00	20.50	30.23
172031-92	103.00	76.00	11.00	11.00	17.00	16.34
172031-93	104.00	82.00	18.00	18.00	17.00	20.20
172031-94	97.00	78.00	14.00	14.00	16.00	16.26
172031-95	98.00	75.20	17.00	17.00	18.20	16.56
172031-96	104.00	106.00	13.00	13.00	24.00	30.88
172031-97	105.00	103.00	10.00	10.00	22.00	15.47
172031-98	105.00	104.00	11.00	11.00	22.00	21.53
172031-99	105.00	76.00	10.00	10.00	21.00	13.85
172031-100	105.00	122.00	10.00	10.00	22.00	17.15
172031-101	123.00	73.00	13.00	13.00	21.00	29.03
172031-102	127.00	107.00	9.00	9.00	16.00	21.82
172031-103	115.00	116.00	10.00	10.00	25.00	13.03
172031-104	113.00	80.00	13.00	13.00	19.00	29.10
172031-105	105.00	115.00	10.00	10.00	25.00	20.00
172031-106	105.00	103.00	10.00	10.00	22.00	24.00
172031-107	105.00	82.00	9.00	9.00	22.00	25.50

LINES	DFF	PH	NT	NP	PL	YPP
172031-108	104.00	75.00	22.00	22.00	20.00	26.00
172031-109	102.00	119.00	12.00	12.00	26.00	15.41
172031-110	102.00	117.00	8.00	8.00	24.00	18.88
172031-111	102.00	81.00	9.00	9.00	20.00	10.32
172031-112	98.00	84.00	9.00	9.00	18.00	15.01
172031-113	99.00	81.00	9.00	9.00	21.00	17.02
172031-114	100.00	113.00	5.00	5.00	23.00	15.15
172031-115	98.00	119.00	6.00	6.00	22.00	13.03
172031-116	97.00	107.00	6.00	6.00	20.00	17.98
172031-117	100.00	102.00	6.00	6.00	20.00	12.41
172031-118	100.00	102.00	10.00	10.00	20.00	24.12
172031-119	100.00	103.00	9.00	9.00	24.00	13.17
172031-120	103.00	110.00	11.00	11.00	23.60	25.90
Mean	**103.45**	**91.06**	**13.08**	**13.05**	**21.22**	**18.32**
Min	**90.00**	**61.00**	**3.00**	**3.00**	**15.00**	**9.14**
max	**127.00**	**122.00**	**34.00**	**34.00**	**28.00**	**39.06**
SD	**6.51**	**15.37**	**5.50**	**5.47**	**2.44**	**5.87**
CV	**6.29**	**16.88**	**42.07**	**41.93**	**11.50**	**32.02**

Fig. 1. Frequency distribution for yield traits in Samba mahsuri/ *O. rufipogon* backcross derived populations







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GENETIC VARIABILITY STUDIES FOR DIFFERENTIAL SOIL PHOSPHORUS CONTENT IN RICE (*ORYZA SATIVA* L.)

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Rice is a self-pollinated cereal crop belonging to the family Gramineae (synomym-Poaceae) under the order Cyperales and class Monocotyledon having chromosome number 2n=24. Rice is the second largest produced cereal in the world in 158.3 million hectare area with annual production of about 685.24 million metric tons (Roy.*et al.*,2001) and also the staple food for over one third of the world's population (Siva Subramanian *et al.,* 1973).

Phosphorus (P) is one of the most important primary macronutrients which promotes plant growth and plays a vital role in improving crop productivity. Nearly 80% of applied inorganic P is wasted in processes such as fixation with iron/aluminum in acidic soils, calcium/magnesium in alkaline soils and slow diffusion leaving only 20% of it to be utilized by the plant. Thus P fertilizer use must be optimised (Yi *et al.,* 2005, Plaxton and Tran, 2011, Vinod and Heuer, 2012, Herrera-Estrella and Lopez-Arredondo, 2016) particularly in India where P fertility of soils is extremely poor (Sanyal *et al* 2015).A critical analysis of the genetic variability parameters, namely, Genotypic Coefficient of Variability (GCV), Phenotypic Coefficient of Variability (PCV), heritability and genetic advance for different traits of economic importance under different soil phosphorus conditions is a major pre-requisite for any plant breeder to work with crop improvement programs. Further, information on correlation coefficients between grain yield and its component characters is essential for yield improvement, since grain yield in rice is a complex entity and is highly influenced by several component characters. The present investigation was undertaken in this context to elucidate information on variability, heritability, genetic advance in promising rice genotypes under variable soil P condition.

The experiment was carried out during *kharif,* 2016 at ICAR-IIRR, Hyderabad The material comprised of 55 elite rice genotypes sown in a randomized complete block design with two replications under three different soil P- viz. 20, 40 and 60 $Kg\ P_2O_5\ ha^{-1}$. Data were recorded on three randomly selected plants in each entry in each replication for the traits like days to 50% flowering, Plant height (cm), total tillers per plant, Productive tillers per plant, spikelet fertility, 1000 seed weight (g) and Yield per plant (g). The data subjected to INDOSTAT 9.1 version software to estimate Genetic coefficient of variation (%), phenotypic coefficient of variation (%), Heritability (%) (Broad sense), Genetic Advance and Genetic Advance as percent of mean. The estimates for variability treated as per the categorization proposed by Siva Subramanian and Madhavamenon.1973, heritability and genetic advance as percent of mean estimates according to criteria proposed by Johnson *et al.*,1995.

In the present study analysis of variance revealed the existence of significant differences among genotypes for all traits studied. The mean, variability estimates *i.e.*, Genetic coefficient of variation (%), phenotypic coefficient of variation (%), Heritability (%) (Broad sense), Genetic Advance as percent of mean are presented in Table 1. All the traits showing mean values increases as the soil P level increases except trait days to 50% flowering which inversely related. All traits under study have higher phenotypic coefficient of variation than genotypic coefficient of variation.

All the characters exhibiting high PCV and GCV in low soil P compare to High soil P condition (Krishnamurthy *et al.*, 2014).

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Table 1. Estimate of Genotypic variability parameters for yield and its components among the fifty five parental lines of rice under Soil P-20, 40 and 60 $kg\ P_2O_5\ ha^{-1}$

Characters	Mean			Range			PCV			GCV			h² (B S)				GAM @ 5%	
	P-20	P-40	P-60	P-20	P-40	P-60	P-20	P-40	P-60	P-20	P-40	P-60	P-20	P-40	P-60	P-20	P-40	P-60
Days to 50% Flowering	111.45	103.93	100.92	92.50 - 128.50	86.00 - 121.50	82.50 - 124.50	8.05	8.41	9.43	7.37	7.68	7.46	83.70	83.40	62.60	15.47	15.02	12.28
Plant Height (cm)	81.49	88.79	94.70	63.17- 98.17	69.17 - 103.82	73.12 - 114.84	12.11	11.36	10.62	11.56	10.63	10.01	91.10	87.60	88.90	18.53	18.20	18.41
Panicle Length(cm)	14.64	17.07	20.80	10.17- 17.91	13.50 - 19.48	17.84- 24.34	11.77	8.58	8.52	10.08	7.48	6.55	73.30	76.00	59.00	2.60	2.29	2.15
Total Tillers per plant	9.76	12.74	15.28	6.34 - 15.1	78.01 - 18.34	12.00 - 19.17	18.31	17.21	14.93	17.38	14.14	9.76	90.10	67.50	42.70	3.32	3.05	2.01
Productive Tillers per plant	8.51	11.16	13.35	5.34 - 14.17	6.50 - 17.00	10.39 - 18.17	19.38	19.14	15.99	17.87	16.91	12.44	85.00	78.00	60.60	2.89	3.43	2.66
Spikelet Fertility(%)	60.90	69.41	78.29	40.64 - 77.92	52.62 - 80.97	57.48 - 87.50	15.41	11.62	9.95	14.76	10.86	8.85	91.70	87.30	79.10	17.73	14.50	12.70
1000 Seed Weight(g)	17.34	18.67	20.27	12.68 - 20.85	14.88 - 22.19	16.97 - 25.69	11.13	8.95	10.08	8.21	7.79	8.62	54.50	75.80	73.10	2.17	2.61	3.08
Yield Per Plant(g)	4.81	9.11	14.92	1.62 - 7.51	3.56 - 14.18	3.03 - 28.65	31.18	25.62	33.25	29.07	20.91	29.69	86.90	66.60	79.70	2.69	3.20	8.15

All the traits studied showing good performance progressively as soil P level increases steadily. Similar results were reported by Fageria *et al.,* (1998), Wisuwa and Ae (2001) and Aluwihare *et al.,* (2016).The magnitude of phenotypic coefficient of variation and genotypic coefficient of variation was moderate in soil P-20 kg P_2O_5 ha^{-1} to low in soil P- 40, 60 kg P_2O_5 $ha^{-1}$for the traits panicle length and 1000 seed weight. (Islam *et al*., 2008). Moderate PCV and GCV were recorded for plant height, total tillers per plant, productive tillers per plant and spikelet fertility in Soil P- 60 kg P_2O_5 ha^{-1} both PCV and GCV were low which is in accordance with Li *et al.,* (2009). The high PCV and GCV were observed for yield per plant (Aluwihare *et al.,* 2016). Genotypic coefficient of variation measures the extent of genetic variability percent for a trait but does not assess the amount of genetic variation which is heritable. Heritability estimates were high for all the characters except total tillers per plant in soil P-60 kg P_2O_5 ha^{-1}. Heritability estimates are high in low soil P compared to that of high Soil P level. Aluwihare *et al* ., 2016 also reported that genotypic variability is well expressed at low soil P. The heritability estimates along with genetic advance can be used to predict effect of selection in selection programmes. The traits like days to fifty percent flowering, spikelet fertility (%) and plant height exhibited high magnitude of genetic advance as percent of mean. Trait yield expressed high heritability but upward increase in heritability as soil P level increases (Tian and Liao 2015 and Samadder, *et al.,* 2018). The traits plant height, days to fifty percent flowering, spikelet fertility (%) and yield have high heritability along with genetic advance as percent of mean indicate that these characters are attributable to additive gene effects which are fixable revealing that improvement in these characters would be possible through direct selection.

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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD, YIELD ATTRIBUTING CHARACTERS AND ECONOMICS OF TURMERIC (*Curcuma longa* L.) var. IISR PRAGATHI

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Turmeric (*Curcuma longa* L.) is an ancient, most valuable and sacred spice of India. It is an herbaceous, perennial belonging to the family of Zingiberaceae. In India, it is cultivated in an area of 2,22,000 ha^{-1} with the production of 10,56,000 MT. (Anon., 2016-2017).The area in Telangana under turmeric cultivation is 60,906 ha with the production of 3,77,616 MT and productivity of 6.2 t ha^{-1}. The main turmeric growing states in India are Telangana (24 %), Andhra Pradesh (22 %), Tamil Nadu (15 %), Orissa (13 %), Assam (6 %), Maharashtra (4 %), Kerala (4 %), Karnataka (3 %) and Gujarat (1 %) (Anon.,2017).

The economic part of turmeric is the dried underground rhizome, valued for it's deep yellow colour and pungent aromatic flavour due to the presence of colouring matter 'curcumin' and an volatile oil 'termerol'. Turmeric held a place of honour in Indian traditional ayurvedic medicine for the treatment of many medical problems such as constipation and skin diseases. It is colouring agent in textile, food, confectionary, cosmetics and drug industries, of late in the preparation of anticancer medicines.

Besides fertilizers, there are several sources of plant nutrients like organic manures, biofertilizers *etc* and these nutrients sources apart from enriching of soil nutrients also improve overall soil health. Organic manures have positive influence on soil texture and structure, better water holding capacity and drainage which inturn help for better rhizome yield and development of rhizomatous crop like turmeric. The use of organic manures in INM help in mitigating multiple nutrient deficiencies.

Application of biofertilizers which are environment friendly and low cost input, with organic and inorganic fertilizers as part of an integrated nutrient management strategy play significant role in plant nutrition and control of pest infestation. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation collectively leading to much higher response on various growth and yield attributing characters (Avitoli *et al.,* 2012).

Keeping in view the importance of aforesaid aspects the present experiment was undertaken to study the effect of integrated nutrient management on yield and yield attributing characters of turmeric (*Curcuma longa* L.) var. IISR Pragathi.

The experiment in turmeric var. IISR Pragathi was carried out at PG Students Research Farm, College of Horticulture, SKLTSHU, during 2018-19 and the experiment was laid out in a randomized complete block design with seven treatments replicated thrice. The treatments *viz.,*T_1: Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + Neem cake(500 kg ha^{-1}), T_2 : Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + *Azotobacter*(2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}), T_3: Farm yard manure (25 t ha^{-1}) + Neem cake (500 kg ha^{-1}) + *Azotobacter*(2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}),T_4 : Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + Neem cake (500 kg ha^{-1})+ *Azotobacter*(2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}),T_5 : 50 % NPK(Recommended Dose Fertilizer) + Farm yard manure (25 t ha^{-1}) +Vermicompost (5 t ha^{-1}) + Neem cake (500 kg ha^{-1}) + *Azotobacter* (2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}),T_6 : 75 % NPK(Recommended Dose Fertilizer) + Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + Neem cake (500 kg ha^{-1}) + *Azotobacter*(2 kg ha^{-1}) +

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Phosphorous solubilizing bacteria (2 kg ha^{-1}), T_7 : Control – 100 % NPK(Recommended Dose Fertilizer). RDF - 50: 60: 108 kg ha^{-1} were included in the experiment

Observations were recorded on yield and yield attributing characters such as number of primary rhizomes plant^{-1}, number of secondary rhizomes plant^{-1}, Fresh weight of rhizomes plant^{-1}(g),Fresh rhizome yield plot^{-1}(kg) in (Table 1).Dry weight of cured rhizomes plant^{-1}, Dry rhizomes yield plot^{-1}(kg), Estimated fresh rhizome yield and cured rhizome yield t ha^{-1} in (Table 2) after harvesting and curing of rhizomes.

All treatments differed significantly with respect to yield parameters. Among the treatments imposed, T_6 recorded significantly highest number of primary rhizomes plant^{-1}(9.31), which was significantly superior to other treatments but was on par with T_5 (8.78), secondary rhizomes plant^{-1} (12.46), which was significantly superior to other treatments but was on par with T_5: (11.30). T_7 (10.53), T_4 (10.43) (Table 1). Maximum dry weight of cured rhizome plant^{-1}(119.00 g) and plot^{-1}(3.68 kg) as compared to other treatments. (Table 2).The lowest number of primary rhizomes plant^{-1}(3.81) was recorded in $T_{1,}$ where as lowest number of secondary rhizomes plant^{-1}(6.40), fresh weight of rhizomes plant^{-1}(302 g) and plot^{-1}(9.06 kg) (Table 1). Dry weight of cured rhizome plant^{-1}(53.15 g) and plot^{-1}(1.59 kg) were recorded in T_2.(Table 2).

The fresh weight of rhizomes plant^{-1}(g) and plot^{-1}(kg)was highest (520.00g,16.00 kg) in T_6 which was significantly superior to other treatments but was on par with T_5(488.00g,15.00 kg).

The increase in yield with integrated nutrient approach might be attributed to the increased growth of plants in respect of height of plant and number of leaves. The healthy top growth might be responsible for the higher rate of photosynthesis, might have accumulated carbohydrates which resulted in increased no of primary rhizomes plant^{-1}, secondary rhizomes plant^{-1} and ultimately the overall yield.Thus the integrated effect of the nutrients might have definitely been responsible for the increase in yield. The results are in conformity with the findings of Rai *et al.*, (2004) in garlic. The combined application of organic manures and biofertilizers which improved soil microbial activities which could help to sustain soil fertility and productivity, might be the reason for higher yield. Dinesh *et al.*, (2010) also found that use of organic manures quickly increases soil microbial activities and plant growth in turmeric.

All the treatments differed significantly with respect to dry wt of cured rhizomes, dry rhizomes plant^{-1}, fresh rhizomes plot^{-1}. Dry weight of cured rhizomes yield plant^{-1}(g) and plot^{-1}(kg)was highest (119g,3.68kg) in T_6 which was significantly superior to other treatments but was on par with T_5 (111g,3.44kg) and T_4(100g, 3.19kg). The lowest dry weight of cured rhizomes yield plant^{-1}(g) (53.15g, 1.59kg)was in $T_{2.}$(Table 2).

Fresh rhizome yield was highest (29.69 t ha^{-1}) in T_6which was significantly superior to other treatments but was on par withT_5 (27.77 t ha^{-1}) and T_7

Table 1. Effect of INM on number of primary rhizomes plant^{-1}, number of secondary rhizomes plant^{-1}, fresh weight of rhizomes plant^{-1}(g), fresh rhizome yield plot^{-1}(kg).

Treatments	Number of primary rhizomes plant^{-1}	Number of secondary rhizomes plant^{-1}	Fresh weight of rhizomes plant^{-1}(g)	Fresh rhizome yield plot^{1}(kg)
T_1	3.81	7.85	323.33	9.60
T_2	3.93	6.40	302.00	9.06
T_3	5.59	8.64	372.20	11.16
T_4	7.78	10.43	414.00	13.09
T_5	8.78	11.30	488.00	15.00
T_6	9.31	12.46	520.00	16.00
T_7	6.81	10.53	475.20	14.25
S.Em±	0.43	0.66	12.00	0.70
C.D.at 5%	1.33	2.04	36.96	2.14

(26.38 t ha^{-1}).The lowest fresh rhizomes yield (16.77 t) was in T_2.

Dry rhizome yield was highest (6.81 t ha^{-1}) in T_6 which was significantly superior to other treatments but was on par withT_5 (6.37 t ha^{-1}) and T_4(5.91 t ha^{-1}). The lowest fresh rhizomes yield (2.98 t ha^{-1}) was recorded in T_2.

*B:C ratio was highest (5.76) in T_4 : Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + Neem cake (500 kg ha^{-1})+ *Azotobacter*(2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}) and the (lowest) B:C ratio (3.03) was recorded in T_2 : Farm yard manure (25 t ha^{-1}) + Vermicompost (5 t ha^{-1}) + *Azotobacter*(2 kg ha^{-1}) + Phosphorous solubilizing bacteria (2 kg ha^{-1}).

Table 2. Effect of INM on dry weight of cured rhizomes plant^{-1}(g), dry rhizome yield plot^{-1}(kg), fresh rhizome yield t ha^{-1}, dry rhizome yield t ha^{-1},B:C Ratio

Treatments	Dry weight of cured rhizomes plant^{-1}(g)	Dry rhizome Yield plot^{-1}(kg)	Fresh rhizome yield t ha^{-1}	Dry rhizome yield t ha^{-1}	Gross income (Rs/ha)	Total cost of cultivation (Rs/ha)	*B:CRatio
T_1	65.00	1.90	17.77	3.51	369250.00	107600	3.43
T_2	53.15	1.59	16.77	2.98	312550.00	103180	3.03
T_3	81.00	2.43	20.66	4.50	472500.00	92680	5.10
T_4	100.00	3.19	24.23	5.91	620200.00	107680	5.76
T_5	111.00	3.44	27.77	6.37	445900.00	109195	4.08
T_6	119.00	3.68	29.69	6.81	476933.33	109952	4.33
T_7	92.30	2.78	26.38	5.15	360266.67	66130	5.44
S.Em±	3.19	0.15	1.2	0.30	25987.78	-	-
C.D.at 5%	9.84	0.46	3.96	0.94	80075.54	-	-

*The price of turmeric for organic treatments was taken @ Rs-1,05,000/t and for INM and Control(100% RDF) treatments @ Rs-70.000/t

Highest dry rhizome yield was recorded with the combined application of FYM, VC and NC along with inorganic fertilizers of NPK. The higher yield might be due to increase in plant height, leaf area, leaf area index number of tillers which might have increased photosynthetic rate due to ready available of the nutrients. Dinesh *et al.,* (2010) reported that 45-48 % higher inorganic nitrogen mineralization in Integrated nutrient management (INM) and organic nutrient management (ONM) are best when compared to chemical nutrient management (CNM) because of increased microbial process. During vermicomposting, the C: N ratio was narrowed down substantially over normal compost. The lower C: N ratio ensures immediate release of nitrogen to plant when applied to soil. (Chaudhary *et al.,* 2004). Similar results were reported by Balakrishnamurthy*et al.,* (2007) in turmeric.

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DRY MATTER AND NUTRIENT UPTAKE OF *RABI* MAIZE AS INFLUENCED BY DRIP FERTIGATION OF NITROGEN, POTASSIUM AND MICROBIAL CONSORTIUM

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Maize is the third most important food crop next to rice and wheat and is not only grown for food and fodder but also for several industrial usage and acquired dominant role in the farming sector and macro-economy of the Asian region (Mauria *et al*., 1998). Water and fertilizers are important production factors for improving maize production and drip fertigation assures an effective and economical way to supply water and nutrients for the crops. Biofertilizers can partially replace chemical fertilizers. Biofertilizers are gaining importance as they are ecofriendly, non-hazardous and non-toxic products. The biofertigation, that is application of liquid biofertilizers or microbial consortium along with drip irrigation can precisely deliver the bioinoculants in the root zone. The present study was planned to evaluate the performance of biofertigation under field condition along with fertigation of inorganic fertilizers on *rabi* maize.

A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *rabi* 2018-19 in randomized block design and replicated thrice. The treatments comprising of two fertility levels *viz.,* 75% and 100% recommended dose (RD) of nitrogen and potassium (N&K) as first factor and biofertigtion of Microbial consortium (MC) *viz*., soil application of MC (SMC), biofertigation of MC three times (MC_3), biofertigation of MC five times (MC_5) and without application of MC (MC_0) as second factor. The recommended dose of (RD) nutrients were 240:80:80 kg $N:P_2O_5:K_2O$ ha^{-1}. The spacing adopted for sowing was 80 cm × 15 cm, experimental soil was loamy in texture, slightly alkaline in reaction, non-saline, low in available nitrogen, medium in available phosphorous and high in available potassium, medium in organic carbon content. N & K was applied in different doses (75% & 100% RDF) through fertigation at an interval of 3 days in the form of urea and SOP (white) and drip irrigation was scheduled at 1.2 Epan during the entire crop growth period. The recommended dose of fertilizers *i.e.,* 240:80:80 kg of N:P2O5:K2O ha^{-1} were applied through fertigation. The entire dose of phosphorus was applied to soil as basal whereas nitrogen and potassium were applied through fertigation at three days interval by dissolving the required quantity of fertilizer as per the crop need $plot^{-1}$ and applied through venturi system. The liquid Microbial consortium consisted of *Azotobacter* (Non symbiotic heterotrophic N_2 fixing bacterium)*,* P solubulizing bacteria, K releasing bacteria and Zn solubulizing bacteria was applied through drip irrigation system @ 1.5 L (with microbial count of 10^{12} cell ml^{-1}) diluted in 500 L of water for one hectare (except for soil application). Fertigation of microbial consortium was started from 10 days after sowing (DAS) at 10 days interval. In three times application the scheduling was at 20, 30 and 40 DAS and in 5 times application it was extended up to 60 DAS. Soil application of microbial consortium was done at 10 DAS @ 1.5 L (with microbial count 10^{12} cell ml^{-1}) mixed with 150 kg of vermicmpost for one hectare and applied along the plant rows. The data generated in this study were analyzed using standard statistical methods through factorial concept.

Results of the study indicated that dry matter production was significantly influenced by fertigation of RD N&K and biofertigation of MC. The interaction effect between RD N&K and biofertigation of MC was not significant at all growth stages *i.e.* 30, 60, 90 DAS and at harvest. There was no significant difference in DMP recorded with fertigation of RD N&K and biofertigation of MC at 30 DAS.

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Fertigation with 100% RD N&K recorded significantly higher dry matter at 60, 90 DAS and at harvest (8563, 17608 and 19081 kg ha^{-1}) compared to 75% RD N&K (7844, 16681 and 18145 kg ha^{-1}).

Increase in dry matter was observed due to increase in fertigation of RD N&K from 75 to 100% and it might be due to higher availability and uptake of nutrients resulting in higher plant height, number of leaves and leaf area plant^{-1} 60, 90 DAS and at harvest resulting in higher DMP with higher fertigation level and these results are in agreement with the findings of Pal (2016), Bibe *et al.* (2017), Patel *et al.* (2017) and Ramdas (2018) in maize.

Among biofertigation of MC, significantly higher DMP at 60, 90 DAS and at harvest was observed in biofertigation of MC five times (8567, 17555 and 19180 kg ha^{-1}) and three times (8389, 17347 and 18957 kg ha^{-1}) than the treatment in which MC was not applied (7693, 16481 and 17785 kg ha^{-1}) and was on par with soil application of MC (8165, 17194 and 18529 kg ha^{-1}). Significantly lower DMP was recorded without application of MC at 60 DAS and at harvest and was on par with the soil application of MC at 90 DAS.

DMP, which reflects the total plant growth, increased with increase in plant height and LAI which might be due to rapid release of nutrients in soil through organic and inorganic resources by *Azotobacter,* PSB, KRB and ZnSB in microbial consortium. Besides these, they also release biologically active substances such as auxins, cytokinins, amino acids and vitamis which could be attributed to increased root growth which in turn enhances the nutrient and water uptake from soil which contributes to more buildup of DMP by plant. These results *i.e.* increase in DMP through biofertigation are in agreement with the findings of Viana *et al.* (2014) in maize, Janat *et al.* (2016) in soybean and Bharathi *et al.* (2017) in bhendi.

N, P & K UPTAKE (kg ha^{-1})

The N, P and K uptake by *rabi* maize was significantly influenced by fertigation of RD N&K and biofertigation of MC at all growth stages except at 30 DAS and the interaction effect was not significant on uptake.

Fertigation with 100% RD N&K recorded significantly higher N, P and K uptake at 60 and 90 DAS (121.1, 28.8 and 108.1 kg ha^{-1} and 169.9, 51.7 and 130.9 kg ha^{-1}) compared to 75% RD N&K (107.5, 26.0 and 97.1 kg ha^{-1} and 158.5, 48.2 and 120.4 kg ha^{-1}, respectively). At harvest, significantly higher N, P and K uptake in stover and grain was recorded in fertigation with 100% RD N&K (72.2, 22.5 and 97.7 kg ha^{-1}, respectively and 129.7, 54.7 and 54.7 kg ha^{-1}) over 75% RD N&K (66.6, 20.9 and 88.7 kg ha^{-1}, respectively and 122.7, 51.9 and 51.4 kg ha^{-1}, respectively). Similarly, significantly higher total N, P and K uptake (202.9, 77.2 and 152.4 kg ha^{-1}, respectively) by maize was recorded with fertigation of 100% RD N&K compared to 75% RD N&K (187.1, 72.8 and 140.1 kg ha^{-1}), respectively.

N, P and K uptake of maize was significantly increased with increase in RD N&K level due to availability of sufficient nutrients in the root zone depth favoring better crop growth, higher dry matter and LAI and resulted in higher uptake of nutrients. These findings *i.e.* increase in uptake with increased fertigation level are similar to results reported by Kumar (2010), Patil *et al*. (2012), Khanna (2013) and Himaja (2016) in maize crop.

There was no significant difference in N, P and K uptake at 60 and 90 DAS, among biofertigation of MC five times, three times and soil application of MC which were significantly superior over without MC. Treatment where MC was not applied recorded significantly lower N, P and K uptake and was par with N, P and K uptake in soil application of MC at 60 DAS and P uptake in soil application of MC at 90 DAS.

At harvest, biofertigation of MC five times recorded higher N and K uptake by stover compared to soil application of MC, without MC and was on par with biofertigation of MC three times. The biofertigation of MC three times recorded significantly higher N and K uptake by stover than without application of MC and was on par with soil application of MC. Significantly lower N and K uptake by stover was observed in without application of MC which was on par with the soil application of MC. There was no significant difference in P uptake by stover among biofertigation of MC five times, three times and soil application of MC and were significantly superior over without MC. There was no significant difference in N, P and K uptake by grain among biofertigation of MC five times, three times and soil application of MC and were significantly superior over treatment where MC was not applied. Significantly lower N, P and K uptake was observed without application of MC and soil application of MC in P and K uptakes but not with N uptake.

Similarly, significantly higher total N, P and K uptake by maize was observed in MC five times (204.5, 77.8 and 153.5 kg ha^{-1}) compared to treatment no MC treatment and was on par with biofertigation of MC three times. Soil application of MC recorded significantly higher total P and K uptake compared to treatment where MC was not applied was on par in total N, P and K uptake wth biofertigation of MC three times. Significantly lower total P and K uptake was observed in treatment where MC was not applied compared to other treatment and was on par in total N uptake with soil application of MC.

The increase in the N, P and K uptakes with biofertigation of MC was due to supply of nutrients indirectly through fixing atmospheric nitrogen by *Azotobacter* applied through biofertigation which colonizes in the rhizosphere and increase the availability and uptake of nitrogen by the plant. Increased uptake of nutrients in response to biofertigation are in accordance with the findings of Jayakumar *et al.,* (2014) in cotton and Shravani (2018) in greengram and Selva kumar (2009)in blackgram.

The results obtained indicated that fertigation with 100% RD N&K recorded significantly higher DMP than 75% RD of N&K at 60, 90 DAS and at harvest. Biofertigation of MC five times and three times recorded significantly higher DMP than the treatment where MC was not applied and was on par with soil application of MC at 60, 90 DAS and harvest.

Fertigation of 100% RD N&K recorded higher N, P and K uptake throughout the crop growth than that of 75% RD N&K. Biofertigation of MC either five times or three times recorded higher N, P and K nutrient uptakes over soil application of MC and without application of MC.

Table 1. Crop dry matter production (kg ha^{-1}) by *rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
RD N&K				
100% RD N&K	591	8563	17608	19081
75% RD N&K	582	7844	16681	18145
SE.m ±	4	142	180	166
CD (P=0.05)	NS	432	546	504
Biofertigation				
MC_0	584	7693	16481	17785
SMC	587	8165	17194	18529
MC_3	588	8389	17347	18957
MC_5	588	8567	17555	19180
SE.m ±	6	201	254	235
CD (P=0.05)	NS	611	772	713
Interaction				
SE.m ±	8	285	360	332
CD (P=0.05)	NS	NS	NS	NS

RD N&K

100% RD (240:80 kg N:K_2O ha^{-1}) ; **75%RD** (180:60 kg N:K_2O ha^{-1}).

Biofertigation

MC_0 - Without Microbial Consortium (MC); **SMC**-Soil application of MC;

MC_3 - Biofertigation of MC three times; **MC_5**-Biofertigation of MC five times.

Table 2. Nitrogen uptake (kg ha^{-1}) by *rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation

Treatment	30 DAS	60 DAS	90 DAS	At Harvest		
				Grain	Stover	Total
RD N&K						
100% RD N&K	13.0	121.1	169.9	129.9	72.2	202.9
75% RD N&K	12.6	107.5	158.5	122.7	66.6	187.1
SE.m ±	0.1	2.9	1.9	1.2	0.9	1.7
CD (P=0.05)	NS	8.8	5.9	3.7	2.9	5.1
Biofertigation						
MC_0	12.6	104.1	155.8	119.0	65.1	182.0
SMC	12.8	113.3	164.5	126.4	68.1	193.2
MC_3	12.8	118.4	166.8	129.2	71.5	200.3
MC_5	12.9	121.5	169.7	130.7	72.9	204.5
SE.m ±	0.2	4.1	2.8	1.7	1.3	2.4
CD (P=0.05)	NS	12.4	8.3	5.2	4.0	7.2
Interaction						
SE.m ±	0.2	5.8	3.9	2.4	1.9	3.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS

RD N&K

100% RD (240:80 kg N:K_2O ha^{-1}) ; **75%RD** (180:60 kg N:K_2O ha^{-1}).

Biofertigation

MC_0 - Without Microbial Consortium (MC); **SMC**-Soil application of MC;
MC_3 - Biofertigation of MC three times; **MC_5**-Biofertigation of MC five times.

Table 3. Phosphorus uptake (kg ha^{-1}) by *rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	30 DAS	60 DAS	90 DAS	At Harvest		
				Grain	Stover	Total
RD N&K						
100% RD N&K	2.6	28.8	51.7	54.7	22.5	77.2
75% RD N&K	2.5	26.0	48.2	51.9	20.9	72.8
SE.m ±	0.1	0.5	0.6	0.7	0.2	0.8
CD (P=0.05)	NS	1.6	1.9	2.0	0.8	2.4
Biofertigation						
MC_0	2.4	25.4	47.4	50.4	20.4	70.8
SMC	2.5	27.1	50.0	53.3	21.4	74.8
MC_3	2.6	28.1	50.7	54.3	22.2	76.6
MC_5	2.6	28.9	51.5	55.1	22.7	77.8
SE.m ±	0.1	0.7	0.9	1.0	0.4	1.1
CD (P=0.05)	NS	2.3	2.7	2.9	1.1	3.4
Interaction						
SE.m ±	0.1	1.1	1.3	1.3	0.5	1.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS

RD N&K

100% RD (240:80 kg N:K_2O ha^{-1}) ; **75%RD** (180:60 kg N:K_2O ha^{-1}).

Biofertigation

MC_0-Without Microbial Consortium (MC); **SMC**-Soil application of MC;
MC_3-Biofertigation of MC three times; **MC_5**-Biofertigation of MC five times.

Table 4. Potassium uptake (kg ha^{-1}) by *rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	30 DAS	60 DAS	90 DAS	At Harvest		
				Grain	Stover	Total
RD N&K						
100% RD N&K	14.0	108.1	130.9	54.7	97.7	152.4
75% RD N&K	13.3	97.1	120.4	51.4	88.7	140.1
SE.m ±	0.3	1.8	2.2	0.9	1.4	1.8
CD (P=0.05)	NS	5.5	6.8	2.7	4.1	5.4
Biofertigation						
MC_0	13.0	94.5	117.6	49.2	87.6	136.8
SMC	13.5	101.6	125.0	53.1	91.7	144.7
MC_3	13.9	105.6	128.8	54.6	95.4	150.0
MC_5	14.1	108.6	131.2	55.4	98.2	153.5
SE.m ±	0.4	2.5	3.2	1.3	1.9	2.5
CD (P=0.05)	NS	7.7	9.6	3.9	5.8	7.6
Interaction						
SE.m ±	0.5	3.6	4.5	1.8	2.7	3.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS

RD N&K

100% RD (240:80 kg N:K_2O ha^{-1}) ; **75%RD** (180:60 kg N:K_2O ha^{-1}).

Biofertigation

MC_0- Without Microbial Consortium (MC); **SMC**-Soil application of MC;

MC_3- Biofertigation of MC three times; **MC_5**-Biofertigation of MC five times.

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Research Note
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EFFECT OF NITROGEN AND ZINC APPLICATION ON MORPHOLOGICAL PARAMETERS AND YIELD ATTRIBUTES IN PADDY (*Oryza sativa* L.)

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In India, rice is grown in an area of 44.5 M ha with a production 115.60 Mt and a productivity of 2800 kg ha^{-1}. Telangana State contributes 2.09 million ha area annually with a production of 6.62 million tonnes, with an average productivity of 3295 kg ha^{-1} during 2018-2019 (CMIE, 2019).The input of nitrogenous fertilizers is closely related to the increase in yield which is a consequence of the increased photosynthetic capacity of the leaves, formation of tillers, differentiation of spikelets and quality of grains (Tanaka *et al.,* 2012). Farmers have the habit of application of excess fertilizers to seek more yield. However, excess application of nitrogen can lead to detrimental impacts such as crop lodging, delay in ripening, poor grain yield and quality (Zhang *et al*., 2014). Excess N leads to low N use efficiency,enormous N losses, high production cost and environmental pollution (Peng *et al*., 2006; Qiao *et al*., 2013).

Zinc is one of the eight essential micronutrients crucial for plant growth and development. Zinc is a major component and activator of several enzymes involved in metabolic activities (Chaudhary *et al*., 2007). Applied nitrogen has been found to have a synergistic effect with zinc in rice. It has been reported that the uptake and concentration of zinc increases substantially with an increase in the nitrogen application rate (Jiang *et al*., 2008). The present study was therefore conducted to evaluate the effect of different levels of nitrogen and zinc foliar spray on growth enzyme activity and yield attributes in paddy.

Field experiment was conducted on sandy clay soil in College farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif* and *Rabi,* 2018. The experiment was laid out in a split plot designwith three replications. The seedlings of different rice varieties V_1- Kunaram Sannalu, V_2- Tella hamsa and V_3- Telangana Sona at 25 days old seedlings were transplanted by adopting a spacing of 15 × 15 cm. Fertilizers were given as N_1 - RDN (120 Kg N ha^{-1}), N_2 - 25% less than RDN (90 Kg N ha^{-1}), N_3 - 25% higher than RDN (150 Kg N ha^{-1}), N_4 - 25% less than RDN + 0.5 % $ZnSO_4$ Foliar spray, N_5 - 25% higher than RDN + 0.5 % $ZnSO_4$ Foliar spray, N_6- Control. The recommended dose of 120:60:40 N, $P2O_5$ and K_2O kg ha^{-1} was applied. Nitrogen was applied in 3 splits at basal, maximum tillering and flowering stage. Similarly, 0.5 % $ZnSO_4$ foliar spray was applied 3 times at tillering, panicle initiation and flowering stage. The data generated was statistically analyzed by using windostat software version 9.2.

The SCMR influenced by nitrogen availability at different growth stages has been widely used to judge nitrogen demand at different growth stages to improve grain yield and to know the nitrogen use efficiency in rice plants. Data on SCMR as influenced by nitrogen and zinc application in rice varieties is presented in Table 1. SCMR values increased from vegetative to flowering stage and thereafter declined towards grain filling stage among the varieties studied. Results revealed maximum SCMR observed at flowering stage and it was found maximum in variety Telangana Sona at all the crop growth stages (36.6, 39.3 and 29.0 at vegetative, flowering and grain filling respectively).

Pooled data suggested that among the various nutrition levels, SCMR recorded maximum at flowering compared to other growth stages and it was observed to be highest in the treatment 25% higher than RDN + 0.5 % $ZnSO_4$(38.4, 40.9 and 31.0 at vegetative, flowering and grain filling respectively).

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It was observed that the SCMR value was higher at vegetative stage and flowering stage, when the nitrogen was efficiently taken from the soil and decreased at grain filling stage which indicated the responsiveness of varieties to nitrogen at vegetative and flowering stage. Similar results were also reported by Verma *et al*. (2004). Application of nitrogen fertilizer increased the chlorophyll content and it was also reported that grain yield was positively correlated with chlorophyll content in rice (Pramanik and Bera 2013). Interaction between varieties and various nitrogen levels was not significant at different growth stages.

Glutamine synthetase plays a key role in nitrogen nutrition and grain yields in rice. In the present study, glutamine synthetase activity in leaf showed increasing trend as crop growth proceeded from vegetative to flowering stage thereafter decreased in all the varieties (Table 1). Significant differences were observed among the rice varieties studied. Among the varieties, GS activity was found highest at flowering and the variety TelanganaSonahad highest GS activity at all stages (3.42, 3.63 and 2.74 µmole glutamine formed min^{-1} g^{-1} FW at vegetative, flowering and grain filling stage respectively), thus probably leading to a better assimilation of inorganic nitrogen as compared to other varieties under study. These results suggests that the nitrogen accumulated in the leaves of Telangana Sona was used more efficiently for grain filling and presumably had a better translocation pathway.

Application of nitrogen had significant effect on activity of glutamine synthetase and it was found to be highest at flowering stage and in the crop supplied with 25% higher than RDN + 0.5 % $ZnSO_4$ maximum activity was observed at various stages (3.69, 3.89 and 2.87 µmole glutamine formed min^{-1} g^{-1} FW at vegetative, flowering and grain filling stage respectively), while the minimum in the treatment control. The interaction between varieties and various nitrogen levels on glutamine synthetase activity was significant at vegetative and flowering while at in grain filling stage it was not significant. Therefore, glutamine synthetase activity is one of the check points in nitrogen assimilation as the product of glutamine synthetase reaction is supplied in constant amount to glutamate synthase (Mokhele *et al*., 2012).

Nitrogen nutrition influences the content of photosynthetic pigments, synthesis of the enzymes taking part in the carbon reduction, formation of the membrane system of chloroplasts, and there by increases growth and yield. Significant differences were observed between the varieties in photosynthetic rate at maximum vegetative, flowering and grain filling stage (Table1). Maximum photosynthetic rate was recorded at flowering stage among the varieties and Telangana Sona has recorded highest photosynthetic rate (15.6 and 21.3 mmole CO_2 m^{-2} s^{-1} at vegetative and flowering stage respectively) minimum at grain filling stage (11.9 mmole CO_2 m^{-2} s^{-1}).

Leaf photosynthetic rate was observed to increase significantly due to increased application of nitrogen. Pooled data revealed that among the fertilizer nutrition levels, the photosynthetic rate recorded maximum at flowering stage and highest rate was recorded in treatment 25% higher than RDN + 0.5 % $ZnSO_4$ (16.8, 22.4 and 12.4 mmole CO_2 m^{-2} s^{-1}at vegetative, flowering and grain filling respectively). The interaction was found statistically not significant between varieties and various nitrogen levels at different growth stages. Hassan *et al*. (2007) suggested low levels of nitrogen can reduce photosynthetic rate as well as leaf chlorophyll content and photosynthetic efficiency.

The number of tillers hill^{-1} is an important yield attribute that accounts for major variation in grain yield of a crop. Data on number of tillers hill^{-1} is presented in table 2. Pooled data showed that highest number of tillers hill^{-1} (17) was found in TelanganaSonafollowed by Kunaram Sannalu(15). The lowest number of tillers hill^{-1} was recorded in Tellahamsa(13). The differences among the varieties for this parameter are statistically significant.

Between the treatments, there was significant increase in number of tillers with increase in nitrogen application 15 to 17 tillers hill^{-1}were recorded. Pooled data was not significant. Nitrogen increases the number of tillers because it favors many metabolic processes within the plant system. There was no significant effect of foliar spray on tiller number either. The increase in tillers hill^{-1} was earlier reported with increase in nitrogen levels up to 120 kg N ha^{-1} (Aruna *et al*., 2012) and 150 kg N ha^{-1} (Ramesh *et al*., 2009).

Table 1. Effect of nitrogen and zinc on physiological parameters in rice varieties at different stages of crop during *kharif* and *rabi*, 2018

Treatment	SCMR Pooled			Glutamine synthetase activity Pooled			Photosynthetic rate Pooled		
	Vegetative	Flowering	Grain filling	Vegetative	Flowering	Grain filling	Vegetative stage	Flowering stage	Grain filling
Main plots : Varieties									
V1	36.0	38.7	28.1	3.32	3.54	2.66	15.2	19.7	11.1
V2	34.7	37.6	26.0	3.23	3.41	2.55	14.9	18.9	10.4
V3	36.6	39.3	29.0	3.42	3.63	2.74	15.6	21.3	11.9
SEm±	0.14	0.05	0.05	0.005	0.004	0.006	0.09	0.03	0.04
p=0.05	0.56	0.19	0.20	0.019	0.014	0.023	0.27	0.15	0.16
Subplots : Fertilizer treatments									
N1	36.2	39.4	28.7	3.43	3.67	2.74	15.9	20.4	11.4
N2	34.7	37.5	26.5	3.31	3.50	2.58	14.7	19.1	10.7
N3	37.8	40.0	30.1	3.60	3.80	2.81	16.2	21.8	12.1
N4	36.1	38.4	27.2	3.37	3.60	2.67	15.3	19.9	11.0
N5	38.4	40.9	31.0	3.69	3.89	2.87	16.8	22.4	12.4
N6	31.1	34.5	22.7	2.54	2.71	2.24	12.7	16.0	9.1
SEm±	0.13	0.08	0.10	0.005	0.005	0.009	0.07	0.10	0.05
p=0.05	0.40	0.25	0.29	0.015	0.015	0.027	0.20	0.31	0.17
Interaction									
Fertilizer treatments at same or different rice varieties									
SEm±	0.24	0.15	0.18	0.012	0.009	0.014	0.12	0.18	0.10
p=0.05	NS	NS	NS	0.028	0.026	NS	NS	NS	NS
Interaction									
Rice varieties at same level of fertilizer treatments									
SEm±	0.26	0.14	0.16	0.009	0.008	0.016	0.14	0.17	0.10
p=0.05	NS	NS	NS	0.030	0.026	NS	NS	NS	NS

Table 2. Effect of nitrogen and zinc on yield attributes and yield during *kharif* and *rabi*, 2018

Treatment	No. of tillers hill^{-1}			No. of panicle m^{-2}			Panicle length (cm)			Grain yield ha^{-1}		
	Kharif	***Rabi***	**Pooled**	***Kharif***	***Rabi***	**Pooled**	***Kharif***	***Rabi***	**Pooled**	***Kharif***	***Rabi***	**Pooled**
Main plots : Varieties												
V1	15	14	15	356	346	351	22.9	22.4	22.7	5002	4848	4926
V2	14	12	13	337	329	333	21.8	21.2	21.6	4220	4076	4148
V3	17	16	17	361	354	357	25.2	24.5	24.9	5140	4959	5050
SEm±	0.11	0.12	0.13	0.49	0.67	0.56	0.05	0.04	0.04	7.78	4.10	5.93
p=0.05	0.44	0.49	0.52	1.98	2.71	2.27	0.20	0.18	0.19	31.39	16.55	23.92
Subplots : Fertilizer treatments												
N1	16	15	16	355	346	351	23.6	23.0	23.4	5060	4896	4978
N2	15	14	15	352	339	345	23.2	22.5	23.0	5023	4873	4948
N3	17	16	17	359	352	356	23.7	23.2	23.5	5115	4953	5034
N4	15	14	15	355	343	349	23.6	22.8	23.2	5039	4899	4969
N5	17	16	16	361	355	359	24.1	23.6	23.9	5129	4969	5049
N6	12	11	12	325	320	323	21.7	21.1	21.5	3358	3178	3268
SEm±	0.22	0.20	0.19	0.45	0.49	0.30	0.07	0.05	0.05	9.83	2.99	5.73
p=0.05	0.65	0.59	0.56	1.31	1.44	0.89	0.22	0.16	0.16	28.52	8.68	16.65
Interaction												
Rice varieties at same level of fertilizer treatments												
SEm±	0.27	0.29	0.31	1.20	1.65	1.31	0.12	0.11	0.11	19.07	10.06	14.53
p=0.05	NS	NS	NS	2.55	2.92	1.89	0.42	0.30	0.31	53.27	17.56	32.20
Interaction												
Fertilizer treatments at same or different rice varieties												
SEm±	0.37	0.3	0.33	0.86	1.03	0.74	0.13	0.09	0.10	17.38	6.26	10.84
p=0.05	NS	NS	NS	2.83	3.50	2.64	0.41	0.31	0.32	54.39	21.22	35.13

Number of panicles is an important determinant of grain yield and is one of the criteria for assessing the grain yield in cereal crops. Pooled data showed between the varieties, the maximum number of panicles were obtained in the variety Telangana Sona(357) followed by Kunaram sannalu and Tella Hamsa in (Table 2). Application of nitrogen at 25% higher than RDN + 0.5 % $ZnSO_4$had resulted in maximum number of panicles m^{-2} (359), while at control minimum panicles m^{-2} (323) was recorded. Similar results were reported by Gosh *et al.* (2013). Interaction effect of varieties and various nitrogen levels was found to be significant.

Panicle length was found statistically significant among the varieties.Interaction suggested maximum panicle length in Telangana Sona (24.9 cm) while nitrogen treatment 25% higher than RDN + 0.5 % $ZnSO_4$had highest panicle length (23.9 cm). Pramanik and Bera (2013) observed increase in panicle length with increase in nitrogen levels and they reported that longer panicle length could be attributed to nitrogen role in panicle formation and panicle elongation.

Grain yield is a complex heritable character influenced by many morphological, physiological and biochemical characteristics of the plant interacting with the environment. Data on grain yield is presented in table 2. Results showed grain yield was found maximum in Telangana Sona (5050 kg ha^{-1}) and with 25% higher than RDN + 0.5 % $ZnSO_4$(150 Kg N ha^{-1}). Statistically significant differences were found among the varieties. Varietal differences observed with respect to the response of grain yield to nitrogen application might be attributed to their leaf area index at the flowering stage.

In the present investigation interaction effect of varieties and various nitrogen levels was found to be significant. At 25% higher than RDN + 0.5 % $ZnSO_4$ application rate, Telangana Sona has recorded maximum grain yield (5049kg ha^{-1}). The higher yield here can be attributed to maximum SCMR values and number of tillers. Similar results were reported by Mahajan*et al.* (2011) and Malla Reddy *et al.* (2012).

Based on the above results it is concluded that the variety Telangana Sona had the best morphology and physiological performance in terms of SCMR, GS activity, photosynthetic rate, tillers $hill^{-1}$, panicles m^{-2}, panicle length and grain yield. Among the fertilizer nutrition 25% higher than RDN + 0.5 % $ZnSO_4$was best treatment and gave maximum yields.

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Research Note
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COST OF CULTIVATION AND RESOURCE USE EFFICIENCY OF GROUNDNUT SEED PRODUCTION IN TELANGANA STATE

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It is well established universally that seed is the basic and most critical input for sustainable agriculture. Quality seed is the pivotal input for sustained growth of agricultural sector and other inputs are contingent upon quality of seed for being optimally effective. Adequate quantity of quality planting material at appropriate time and affordable cost is the objective of the policy makers in order to bring radical changes in agricultural scenario of our country.

In India, The total seed production of groundnut was 17.95 lakh quintals during the year 2016-17. (Ministry of Agriculture & Farmers Welfare, Govt. of India 2017-18).

Telangana state is involved in production and supply of good quality seed to farmers all over India and also to other countries. In Telangana state, total area registered under seed production was 179178 acres and the total quantity of certified seed produced was 1690732 quintals during the year 2017-18. The area registered under groundnut seed production was 18761 acres with production of 86064 quintals of certified seed (Department of Agriculture, Telangana, Govt. of Telangana, 2017-18).

Multistage sampling technique was adopted for selection of the sample district as the first stage, mandals as the second stage, villages as the third stage and respondents as the final and ultimate stage. Mahabubnagar district was purposively selected as the area under groundnut seed production was the highest in this district. Similarly, based on the highest acreages under the seed crop, Midjil and Uppununthala mandals were selected. Midjil and Boinpalle villages from Midjil mandal, Penmilla and Uppununthala villages from Uppununthala manadal were identified. About 25 registered farmers from each village were randomly identified and the primary data was collected with the help of pretested questionnaire.

The data collected was compiled and tabulated to draw valid inferences from the study. Simple percentages and averages were also used to compute and compare the results of the study.

The cost concepts *viz.*, cost A_1, cost A_2, cost B_1, cost B_2, cost B_3, cost C_1, cost C_2 and cost C_3 which are generally followed in farm management studies were adopted for the present study and examined.

The various income measures were also worked out to assess the efficiency of groundnut seed production in the study area.

Besides, Cobb-Douglas production function was employed to estimate the resource use efficiency in seed production.

The Cobb-Douglas production function is linear in logarithmic form and is expressed in the following general form.

$$Y = a\, x_1^{b1}\ x_2^{b2} \ldots\ldots\ldots x_n^{bn}$$

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + \ldots\ldots + b_n \log X_n$$

In this case the function is expressed as

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 \log X_5 + b_6 \log X_{6+} b_7 \log X_7$$

$X_1, X_2, X_3, X_4, X_5, X_6, X_7$ are all parameters affecting the level of Y.

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$b_1, b_2, b_3, b_4, b_5, b_6, b_7$ are elasticity coefficients

'a 'denotes a constant.

In the above equation:

Y = Gross income in Rs per hectare

X_1 = Total labour

X_2 = Machine power

X_3 = Seed

X_4 = FYM

X_5 = Fertiliser

X_6 = Pesticide

X_7 = Irrigation

Thus, seven independent variables and one dependent variable were selected for fitting the Cobb-Douglas production function to test the productivity of the resources used in seed production.

Finally , the returns to scale were estimated directly by getting the sum of 'b_i' coefficients.

The cost and returns from groundnut seed production in the study area of Mahabubnagar district is presented in the Table 1.

Table 1. Item wise comparison of costs in groundnut seed production

S.No.	Item	Cost in rupees
I	**Operational costs**	
1	Human Labour	17000(21.61)
	Hired Labour	12500(15.89)
	Owned labour	4500(7.72)
2	Machine power	12844(16.32)
3	Seed	9386(11.93)
4	Manures and fertilizers	8700(11.06)
5	Plant protection chemicals	8002(10.17)
6	Irrigation charges	800(1.01)
7	Miscellaneous charges	1269(1.61)
8	Interest on working capital	1378(1.76)
	Sub total	59379(75.47)
II	**Fixed costs**	
9	Depreciation on implements and farm buildings	1005(1.28)
10	Rental value of owned land	14550(18.50)
11	Interest on owned fixed capital (excluding land)	3737(4.75)
	Sub total	19292(24.53)
III	**Total cost**	78671(100.00)
	Yield (Qtl)	24

Note: Figures in parentheses indicate the per cent to respective column total

The table reveals that the major cost component in the groundnut seed cultivation is the human labour which accounts for 21.61 per cent of the total cost of 78671 per hectare. Groundnut crop is mostly infested with weeds and weeding operations involves human labour and therefore resulting in the major cost item.

The other major cost component is the machine labour accounting to 12844 per hectare (16.32 per cent). The other costs like seed, manures and fertilizers and plant protection chemicals worked out to 11.93 per cent, 11.06 per cent and 10.17 per cent in the same order. The irrigation charges and other items of operational costs are between 1-2 per cent of total cost. Among the fixed costs component rental value of owned land (14550), followed by interest on capital (3737) and depreciation (1005) were the various cost items accounting to 19292 per hectare.

Thus, the two major cost items under operational and fixed cost components are cost of human labour and rental value of owned land respectively. The cost can be reduced by adopting mechanisation with small equipments. The yield in the study area worked out to 24 quintals per hectare.

The cost concepts and income measures were worked out in order to have a better understanding of the viability of the activity.

The results presented in Table 2 shows that the cost C_1 component was 64121. Similarly, the income measures were worked out and the returns per rupees spent was 1.46. Whereas, the value of the main product at the rate of 5100 per quintal was 122400. The value of by product added upto 4320. The overall gross income when added resulted in 126720 and the net income resulted in 40182. Though the gross income is a measure to assess the efficiency of the farm business, but it alone does not help to read its success. Therefore, other measures like farm business income which indicates returns to owned resources like land, capital and labour were worked out. The value of the farm business income was 70836 followed by family labour income (52549) and farm investment income (66336).

Table 2. Comparison of costs according to cost concepts and income measures in groundnut seed production

S.No.	Item	Cost in rupees
I	**Cost concepts**	
i	Cost A_1	55884
i	Cost A_2	55884
iii	Cost B_1	59621
iv	Cost B_2	74171
v	Cost C_1	64121
vi	Cost C_2	78671
vii	Cost C_3	86538
II	**Income measures**	
i	Yield (q/ha)	24
i	Price (¹ /q)	5100
iii	Value of main product(¹ /ha)	122400
iv	Value of by product(¹ /ha)	4320
v	Gross income (¹)	126720
vi	Net income (¹)	40182
vii	Farm business income (¹)	70836
viii	Family labour income (¹)	52549
ix	Farm investment income (¹)	66336
x	Returns per rupee spent	1.46

Thus, the above analysis indicates that groundnut seed production is profitable and gave good productivity out of the resources available at the farm. These findings are in conformity with those of Govind Pal *et al*., (2016), Sowjanya (2011) who concluded that the income measures were positive and returns per rupee investment was reasonably good in case of groundnut seed production.

The estimates of the production function is presented in Table 3. The variables included in the function explained 69.00 per cent of the variation in production of groundnut seed production

The elasticity coefficient of machine power (X_2) and FYM (X_4) were found to be significant with positive sign, indicating that every one per cent increase in expenditure on each one of them would increase the gross income by 0.25 and 0.56 per cent respectively.

Table 3. Summary of regression analysis of Groundnut seed production

S.No.	Particulars	Coefficients	p-value
1	Intercept	-22.07 ***	2.53E-10
2	Human labour	-0.33 ***	0.000972
3	Machine power	0.25 ***	1.7E-34
4	Seed	-0.06	0.33
5	FYM	0.56 ***	3.01E-05
6	Fertilizer	0.45	0.66
7	Pesticide	-0.23 **	0.02
8	Irrigation charges	0.35	0.07
	R^2	0.69	
	Returns to scale	0.99	

Note: *** significant at 1% level, ** significant at 5% level * significant at 10 % level.

However, the regression coefficient values of human labour (-0.33) and pesticide (-0.23) was found negative but statistically significant indicating that farmers used more labour and excess of pesticides than required in groundnut seed production. The coefficient value of seed (-0.06) was negative but non-significant in selected groundnut seed production farms.

The regression coefficient of fertilizer (X_5) and irrigation charges (X_7) were found to be statistically insignificant in groundnut seed production indicating that they do not contribute significantly to the gross income in sample groundnut farms.

Returns to scale of 0.99 indicates decreasing returns to scale of groundnut seed production. This indicates that, still there is scope for reorganization of resources i.e., human labour and pesticides which were presently over-utilized.

From the results it can be concluded that the groundnut seed production in the Mahabubnagar district in Telangana state during the year 2016-17 has yielded an average return of Rs 126720/ha with the returns per rupee spent was 1.46. Human labour and machine labour have accounted for the highest share in the total cost of cultivation of Rs 29844/ ha (21.61 and 16.32%, respectively). The elasticity coefficients for groundnut seed production, machine power and Farm Yard Manure provided are 0.25 and 0.56, respectively. The return to scale was found less than one, it means that the deceasing return to scale. The return per rupee spent on groundnut seed production was observed as 1.46. The groundnut seed producers received 1.46 rupees in place of one rupee invested in the seed production. It means that the groundnut seed production activity is profitable.

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