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Integrated effects of organic manuring, NPK and foliar fertilization on growth, yield and quality of groundnut and pigeonpea in legume based intercropping system

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Abstract
Boosting the yield, improving soil health and maintaining human health are the three interlinked components of the sustainable triangle. There is increasing evidence that fertilizers alone cannot sustain crop yields for longer periods because crops hardly utilize 30 to 40 percent of the applied fertilizer nutrients and the rest is lost in to the ecosystems and degrading it. It can be minimized through integrated application of organic manures, NPK, foliar fertilization of zinc, DAP and NAA. Biofortification of legumes with zinc also alleviate malnutrition. Field experiments were carried out in a Farm at Chandirambadi in Vandavasi, Tiruvannamalai District in the North-Eastern agro-climatic zone of Tamil Nadu during *Kharif* and *Rabi* seasons of 2019 and 2020 to study the effect of INM practices on the growth, yield, and quality of groundnut (*Arachis hypogaea* L.) and pigeonpea (*Cajanus cajan* (L.) Millsp.) in legume based intercropping system. The experiments were laid out in Randomized Block Design and were replicated thrice with seven treatment combinations *viz*., Control, 75/100/125% RDF + Vermicompost (5/4/3 t/ha) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut and without or with DAP 2% & NAA 40 ppm Foliar Spray to Pigeonpea. The pooled data results revealed that significantly highest plant height (58.69 cm), LAI (4.28), No. of effective nodules/ plant (98.43), DMP (5814 Kg/ha) and CGR (14.65 g/m^2/day), No. of pods/ plant (25.78), shelling percentage (73.02), pod yield (2087 kg/ha), kernel yield (1565 kg/ha), oil content (49.74%) and crude protein (26.38) for groundnut and the maximum plant height (216.62 cm), LAI (3.86), DMP (3790 kg/ha) and CGR (26.12 g/m^2/day), pods/plant (208), number of seeds/pod (4.68), seed yield (658 kg/ha) for pigeonpea and the highest groundnut equivalent yield (1316 kg/ha) were observed under application of 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm). However, it was statistically on par with application of 75% RDF (12.75: 25.5: 40.5 kg N, P_2O_5 and K_2O ha^{-1}) along with Vermicompost (5 t ha^{-1}) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm). The highest Kernal Zn content of 51.65 mg/kg and B: C ratio of 3.5 were recorded in 75% RDF and its combinations treatment.

Keywords: Biofortification, foliar nutrition, growth regulators, intercropping, legumes, zinc

Introduction
India is a proud nation enjoying self-sufficiency in food grain production and sustainable food security despite burgeoning population and innumerable climate related stresses. But there is difficult to think satisfaction, because country is still facing severe challenges in pulses and oilseed sectors. Pulses in India have long been considered as the Poor man's protein. The per capita availability of pulses declined from 60.54 grams in 1950-51 to 53.00 grams in 2021-22 against the minimum requirement (ICMR norms for sedentary activity) of 68.49 g/day, and as against WHO recommendation of 80g/day (Minhas, 2023a) [21]. In order to ensure self-sufficiency, the pulse requirement in the country is projected to be 32 million tonnes by 2030.
The availability of vegetable oil from domestic production of nine annual oilseed crops would be about 13.69 million metric tonnes by 2022. India consumed an estimated volume of 23.45 million tonnes of vegetable oil in 2022-2023 (Minhas, 2023b) [22]. Groundnut (*Arachis hypogaea* L.), 'the 'King' of oilseed and poor man's almond (or) wonder nut', world's fourth most important sources of edible oil and third most important sources of vegetable protein, is prime to the financial and nutritional well-being of hundreds of millions of resource poor farmers and consumers across the semi-arid tropics. It is widely cultivated in rainfed regions (Bhosale *et al.*, 2017) [6].

Apart from the nutritional benefits, the high consumption of groundnut oil and value-added products derived from the groundnut kernel assures the survival of low-income farmers (Ramprosad Nandi *et al*., 2020) [30].

In India, it is being cultivated in an area of 5.74 million ha and 6.66 million tonnes of total production with an average productivity of 1210 kg/ha (USDA, 2023) [37]. The national average productivity is less than the world average and the top producer (China) 3800 kg/ha. In Tamil Nadu, groundnut is cultivated in an area of 1.1 million ha with production 1.23 lakh tonnes with an average productivity of 1713 kg/ha. According to FAO, worldwide Pigeonpea (*Cajanus cajan* (L) Millsp.) was grown in about 6.36 million hectares with a production and productivity of 5.48 million tonnes and 861 kg/ha, respectively (FAO, 2021) [9]. In India it is grown in an area of 4.98 million ha with a production of 4.34 million tonnes and productivity of 871 kg/ha (COR, 2023). It can be an ideal crop in groundnut based intercropping system (Jadhav *et al*., 2017) [14]. In Tamil Nadu, Dharmapuri, Selam, Theni, Namakkal, Madurai, Vellore, Thiruvannamalai, etc. are most efficient cropping zone for pigeonpea.

Crop intensification in both the time and space dimensions is one of the ways to enhance the productivity of crops (Rex Immanuel *et al*., 2019; Hussain *et al*., 2023) [32, 12]. Intercropping is considered to be an effective and potential means of increasing crop productivity, particularly in marginal and small holdings under rainfed regions. It provides an efficient utilization of natural resources, decreases the cost of production, provides financial stability, decreases the pest and disease incidence, intercropping system smothers weeds growth, improves soil fertility and increases crop yield along with improves quality of produce is possible in intercropping when compared to sole cropping system (Choudhari *et al*., 2017; Kamara *et al*. 2017; Rex Immanuel *et al*., 2020; Chunjie *et al*., 2023) [7, 16, 32, 8].

Legume based intercropping provides greater stability than sole cropping (monocultures) in terms of soil fertility improvement, yields enhancement and financial returns (Legodi and Ogola, 2020) [19]. Groundnut and pigeonpea intercropping proved advantageous because groundnut is a short duration crop which utilizes resources effectively in the early season and pigeonpea being medium/long duration, slow-growing and indeterminate type can utilize the resources effectively during post monsoon season. Growing of pigeonpea as an intercrop even in high input agriculture to enhance total pulses besides increasing system productivity and profitability (Ngwira *et al*., 2016) [23].

Mineral nutrition of plants is vital for controlling physiological, biochemical processes and improving yield. In commercial farming, the use of inorganic fertilizers cannot be ruled out entirely. Years of relying exclusively on unbalanced NPK has resulted in nutritional deficits and soil degradation (Venugopal and Mohana, 2021; Jing *et al*., 2022) [38, 15]. Micronutrient deficiency can greatly affect plant yield and quality and the health. The addition of micronutrients boosts crop yields and improves the effectiveness of NPK use when applied in a balanced manner with macronutrients (Bana *et al*., 2022) [3].

Application of micronutrients through foliage of crops can be from 10 to 20 times as efficient as soil application. Globally, zinc (Zn) is currently recognized as the 5th major nutrient deficiency in human beings mainly due to its deficiency in the soil. Zn has specific and essential physiological functions in plant metabolism, influencing yield and quality (Izydorczyk *et al*., 2020) [13]. Hence, there is a need for combined application of organic manures such as vermicompost and inorganic nutrients for sustaining the desired crop productivity.

High consumption of cereal-based foods with low concentration and poor bioavailability of zinc like micronutrients is considered to the main cause of zinc deficiency in humans. Agronomic biofortification involves the use of Zn fertilization, can increase both crop yield and grain Zn concentration in crops (Khokhar *et al*., 2020) [18]. Zn biofortification to crops enhances per unit area productivity and grain Zn concentration, thereby contributing to increasing the yield and the grain's nutritional value for human consumption (Bhat *et al*., 2023) [5]. Therefore, biofortifying groundnut with zinc is an effective approach to lessen zinc malnutrition in in developing countries. Further, in determining the yield and quality of groundnut, the role of Zn is much pronounced.

Foliar application of nutrients plays a key role in pulses production compare to soil application. It has ability to advance the efficiency and speed of utilization of a nutrient urgently required by the plant for maximum growth and yield (Kandil and Eman, 2017) [17]. Foliar spray of DAP met constant requirement of nitrogen and phosphorous at reproductive stage of the crop which in turn favoured photosynthetic ability and increased accumulation and efficient portioning of photosynthates towards sink (Gnyandev *et al*., 2019; Priyanka *et al*., 2019) [11, 28]. Considering these facts, the present experiment was under taken to evaluate the INM practices for the growth, yield and economics of groundnut + pigeonpea intercropping system.

Improved intercropping systems and nutrient management practices offers the possibility of field stability by increasing yield per unit area of land, reducing risk of total crop failure, reduction in farm inputs especially pesticides, herbicides, inorganic fertilizers and increased labour efficiency and provides diversified needs of the small farmers and marginal farmers. Keeping in view the key role played by organic, inorganic and growth regulators in plant growth, productivity and quality of crops, field experiments were designed to find out the suitable INM practices for augmenting groundnut and pigeonpea production in a legume based intercropping system under semi-arid situations of North-Eastern agro-climatic zone of Tamil Nadu.

Materials and Methods

Field experiments were carried out in an Experimental Farm at Chandirambadi in Vandavasi, Tiruvannamalai District, in the North-Eastern agro-climatic zone of Tamil Nadu during '*Kharif*' and '*Rabi'* season of 2019 - 2020 to study the combined INM practices and foliar application of nutrients on the growth, yield, and quality of groundnut and pigeonpea in legume + legume intercropping system. The experimental site is geographically located at 12^{o} 57$^{'}$ North latitude and 79^{o} 43$^{'}$ East longitude with an altitude of +168 m above mean sea level.

The weather of study area is moderately warm with hot summer months. The weekly mean maximum temperature during cropping period ranges from 25.2 °C to 40.8 °C with mean of 35.6 °C and the weekly mean minimum temperature fluctuates between 22.7 °C and 28.3 °C with a mean of 25.9 °C. The relative humidity ranged from 52 to 85 percent with a mean of 68 percent. The study area received the rainfall is

601mm distributed over 28 rainy days during cropping period. The texture of the experimental field comprised of clay loam soil with 14.8% coarse sand, 35.2% fine sand, 16.2% silt, 33.8% clay, pH of 7.3, 0.61% organic C (low), 201 kg/ha available N (low), 11.9 kg/ha P_2O_5 (medium) and 290 kg/ha K_2O (high).

The experiments were laid out in a Randomized Block Design and replicated thrice with seven treatment combinations *viz*., T_1 - Farmer's practice as control, T_2 - 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Water spray to pigeonpea; T_3 - 100% RDF + Vermicompost (4 t ha^{-1}) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Water spray to pigeonpea; T_4 - 125% RDF + Vermicompost (3 t ha^{-1}) to Groundnut+ Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Water spray to pigeonpea; T_5 – T_2 + DAP 2% & NAA 40 ppm Foliar Spray to Pigeonpea; T_6 – T_3 + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm); T_7 – T_4 + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm).

For the base crop, groundnut variety TMV 7 was selected and Pigeonpea (VBN (Rg) 3) used as an intercrop in this study. Groundnut + pigeonpea was sown in planting pattern of 6:1 ratio. For the base crop, 30 × 10 cm spacing was used while 180 × 30 cm spacing was used to the intercrop. Gap filling was done on 7th days after sowing and the thinning was done on 15th days after sowing in order to maintain optimum plant population.

A pilot survey was conducted at Chandirambadi region in Thiruvannamalai District for nutrient management practices in groundnut cultivation. Accordingly, in an average, biannually the farmers were used 4 t/ha of Farm Yard Manure (FYM) and 25: 10: 0 kg NPK/ ha and 200 kg/ha of Gypsum to groundnut. The RDF schedule of groundnut *viz.*, 17 kg N, 34 kg P_2O_5, and 54 kg K_2O/ha was adopted in this study. Urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) fertilizers were used to supply N, P and K nutrients, respectively. A half dose of nitrogen was applied basally and the remaining half doses of nitrogen were applied by top dressing. In addition, as per the treatment schedule the prescribed quantity of organic manure (vermicompost) was applied and it consisted of 2.6% N, 1.7% P_2O_5 and 1.2% K_2O. Foliar application of 0.5% aqueous solution of zinc sulphate thrice at 40, 55 and 70 days were applied to the groundnut crop. Two percent DAP solution was uniformly sprayed once at flowering and another at 15 days thereafter. NAA 40 ppm first sprayed once at pre-flowering and second spray at fortnight interval was applied as per the treatment schedule.

Pre-emergence application of fluchloralin @ 1.0 kg *a.i* /ha was done on 3rd days after sowing followed by one hand weeding on 25th days after sowing for control of weeds. Then earthing up was done on 45th days after sowing to encourage peg formation. In pigeonpea nipping practice was carried out on 50 DAS at 5 – 6 cm from the top which helps in branching. Based on Economic Threshold Level need-based plant protection measures were adopted based on the occurrence of pests and diseases.

The height of the plant was measured from the ground level up to tip of the unfold leaf for each treatment at harvest and the mean was expressed in cm. The leaf area index was computed as suggested by Padalia and Patel (1980) [25] by using the following equation.

$$LAI = \frac{Length\ (cm) \times breadth\ (cm) \times 0.70 \times Number\ of\ leaves/plant}{Spacing\ adopted}$$

Crop growth rate (CGR) represents dry weight gained by unit area of crop in a given time. Expressed as g/m^2/day. CGR was calculated by equation given by Fisher (1981).

$$\mathrm{CGR} = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{p(t2} - \mathrm{t1)}} \times 100$$

Where, W_1 – dry weight @ t_1 time, W_2 – dry weight @ t_2 time and ρ - land area (m^2) over which dry matter was recorded.

The sample plants were carefully uprooted without damaging the root nodules at maximum flowering stage (50 DAS) and the pink coloured nodules were counted and expressed as number of effective nodules/plants. The matured plants were harvested, first air dried followed by oven dryed at 80 ± 5°C for 24 hours and weighed and DMP was expressed in kg/ha.

At the time of harvest, the number of pods/plants was recorded from five tagged plants and then mean was arrived. The crops were harvested at their physiological stages of maturity. Harvesting of groundnut was done by manual uprooting of whole plants followed by stripping of pods. One hundred pods from each plot were selected at random and weighed. After hand shelling, kernel weight was recorded. The ratio of kernel to pod weight was calculated and expressed as shelling percentage.

The Groundnut Equivalent Yield (GEY) was calculated from the ratio of price unit weight of the concerned crop by the price unit weight of groundnut (Verma and Modgel, 1983) [39].

$$\mathrm{GEY} = \frac{\text{Grain yield of intercrop (kg/ha)} \times \text{Price of inter crop (Rs/ha)}}{\text{Market price of groundnut (Rs/kg)}}$$

The oil content was extracted from seeds of groundnut from each plots with the help of Soxhlet (SOCS PLUS model SCS-02 R) solvent extractor using n-hexane as solvent. Crude protein content of seed was calculated by multiplying the nitrogen percentage of the kernel with factor 6.25 and expressed in percentage (Humphries, 1956) [12]. Based on the prevailing market rates, the net income was arrived by deducting the cost of cultivation from the gross income. The benefit cost ratio (B:C ratio) was worked out by dividing the gross income by cost of cultivation. The statistical analysis of the data was carried out as suggested by Panse and Sukhatme (1989) [26]. The critical differences were worked out at 5% probability level for comparison. If the absolute difference between the treatments are greater than the critical difference, the treatments are considered to be significantly different otherwise non-significant.

Results and Discussion

Intercropping is popular among the farmers of small holdings because of flexibility of sowing and planting dates, profit maximization, risk minimization, soil conservation, soil fertility maintenance, weed control, higher productivity and nutritional reason. Among the legume based intercropping system, groundnut with pigeonpea intercropping system performs better in terms of productivity when good cultivars are grown under appropriate nutrient management practices.

Growth attributes of groundnut

The growth attributes of groundnut were varied significantly due to INM practices. Among the treatments tested, significantly highest plant height (58.69 cm), LAI (4.28), No.

of effective nodules/ plant (98.43), DMP (5814 Kg/ha) and CGR (14.65 g/m^2/day) were observed under application of 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6) and it was statistically on par with application of 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5).

The enhanced growth attributes might be due to synergistic and cumulative effect of combined use of organic and inorganic nutrient application. The positive effect of N, P_2O_5 and K_2O along with vermicompost on plant height and LAI could be due to the fact that the added fertilizers meeting the immediate nutrient requirement of the crop in the early growth stages by enhancing the availability of soil nutrients. These macro nutrients are the key constituents of chlorophyll biosynthesis, protein, nucleic acid and other constituents and vigorously induced the growth of groundnut. The present findings are in conformity with the observation recorded by Purbajanti *et al*. (2019) [29] and Orji *et al*. (2022) [24].

The enhanced values of DMP could be due to the integrated use of vermicompost, inorganic NPK nutrition and zinc which sustained the availability of all nutrients throughout the groundnut growth period. It contains higher nitrate, which is more available form of N to promote luxury growth and also enriched in certain metabolites and vitamins that helps to enhance the growth parameters like plant height, LAI, number of leaves, root elongation and number of effective root nodules/plant. The present findings are in line with Bekele *et al*. (2019) [4].

The significant increase in CGR could be mainly due to the production of more dry matter which intern indicates higher leaf area production in crops due to early establishment and higher photosynthetic activity. The optimum utilization of resources and better availability of N_2 through biological N fixation by groundnut and pigeonpea makes enhanced utilization of available resources by the groundnut are important reasons behind higher growth characters of groundnut under groundnut + pigeonpea intercropping system. These results are line with the earlier finding of Bekele *et al*. (2019) [4] and Maitra *et al*. (2021) [20].

Yield attributes and yield of groundnut

The maximum No. of pods/ plant (25.78), shelling percentage (73.02), pod yield (2087 kg/ha), kernel yield (1565 kg/ha) and haulm yield (4138 kg/ha) were recorded under application of 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6) and it was statistically on par with application of 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5). However, the test weight (35.13 g) was not significant. This might be due to the complementary interactions between groundnut and pigeonpea and the cumulative and synergistic effect of applied N, P and K along with vermicompost, foliar fertilization of Zn-EDTA.

Being a leguminous crop groundnut fixes significant quantity of atmospheric nitrogen in the soil and converts insoluble form of soil nutrients into available forms by secreting organic acids. It resulting in effective utilization of both applied and soil nutrients by crop which in turn resulted with better protein synthesis, positive metabolic process, cell division, root development and dry matter assimilation leading to an efficient absorption and translocation of water and nutrients, interception of solar radiation and assimilation of carbon dioxide. The catalytic or stimulatory effect of zinc on most of the physiological and metabolic process of plants and biosynthesis of IAA, which indirectly results in initiation of primordial reproductive part and portioning of photosynthetic towards them which ultimately promotes the kernal yield of groundnut (Sudakar *et al*. 2019) [36]. Moreover, highest yield is mainly due to variation in translocation of photosynthates from source to sink as there is greater availability of light due to different growth habit and efficient use of applied nutrients, less competition for resources by component crops. Similar findings have been reported by Shwethanjali *et al*. (2018) [33] and Singh and Srivastava (2018) [34].

Quality parameters of groundnut

Significantly highest oil content (49.74%) and crude protein (26.38) content were recorded in application of 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6) and it was on par with application of 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5). The highest Kernal Zn content of 51.65 mg/kg was recorded in 75% RDF and its combinations (T_5) treatment.

The combined application of inorganic fertilizers, vermicompost and zinc might be associated with improved availability and uptake of all the essential nutrients required for enhanced oil synthesis such as K, Fe and Zn (Choudhari *et al*., 2017) [7]. Further vermicompost is rich in Zn which is very important element in biosynthesis of oil in seeds. Potassium and Zn enhancing enzymes activity promotes the conversion of plant metabolites into proteins and metabolism of lipids. It might have resulted in increased oil content of groundnut. These results are in conformity with findings of Patel *et al*. (2018) [27].

Growth attributes of pigeonpea

Integrated application 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6) recorded the maximum plant height (216.62 cm), LAI (3.86), DMP (3790 kg/ha) and CGR (26.12 g/m^2/day). It was on par with application of 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5).

It might be attributed due to readily available nutrients from vermicompost, applied N, P and K which enhanced availability of nutrients even at initial stage of crop growth. Further, in this cropping system groundnut and pigeonpea are the legume crops, which fixes the atmospheric nitrogen in to the rhizosphere soil and it was effectively utilized by pigeonpea whenever necessary which leads to very less chance of N deficiency, and enhanced the vegetative growth. Further, foliar application of DAP and NAA which contains readily available nutrients in the form of nitrates, exchangeable phosphorus and growth hormones which are easy absorbed by the plant shoots. These involved in cell division and cell elongation, increase in photosynthetic

activity and better accumulation of photosynthates. Hence, there was a boost in the growth characters of pigeonpea especially grown under groundnut + pigeonpea intercropping system. Similar findings were reported by Anjana *et al*. (2020) [1].

Yield attributes and yield of pigeonpea

Significantly maximum number of pods/plant (208), number of seeds/pod (4.68), seed yield (658 kg/ha) and stalk yield (3083 kg/ha) were registered with integrated application of 100% RDF along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6) and it was on par with application of 75% RDF + Vermicompost (5 t ha $^{-1}$) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5).

The increased yield attributes might be due to higher nutrient uptake and increased photosynthetic efficiency as evident from higher LAI values. The constant release of nutrient supplemented by vermicompost in conjunction with inorganic N, P_2O_5 and K_2O fertilizers might have satisfied the demand of the pigeonpea crop at every phenophases increased the photosynthetic efficiency, partitioning of photo assimilates and exhibited efficient translocation of assimilates to the sink. Moreover, foliar application of DAP and NAA at flower initiation and pod formation stage might have improved the reproductive development of pigeonpea and supported efficient translocation of photosynthates from source to sink. This cumulative contribution of these nutrients significantly increased the number pods/plant, number of seeds/pod and yield of pigeonpea. The results are in line with the findings of Ashutosh Barthwal *et al*. (2018) [2].

Vermicompost might help in conductive rhizosphere microclimate for microorganisms which encouraged fast effective root nodulation and fixed more atmospheric nitrogen in the roots of the plant and fixed nitrogen effectively utilized by the pigeonpea. The grain yield of pigeonpea crop was increased due to cumulative effect of yield attributing characters, enhanced photosynthetic efficiency and improvement in the capacity of the reproductive sinks to utilize the incoming assimilates due to the foliar application of DAP and NAA. NAA has beneficial role on preventing flower drop which may be due to creation of favourable balance of endogenous hormone related to flowering which in turn results in increase of seed yield of crops. The present findings are in line with Gnyandev *et al*. (2019) [11].

Groundnut equivalent yield and economics

The highest groundnut equivalent yield (1316 kg/ha) was recorded under application of 100 percent recommended dose of fertilizers along with vermicompost @ 4 t/ha + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_6). This might be due to better performance and yield of both the component crops under intercropping system and price of commodities and efficient utilization of resources, time and space helped in increasing the groundnut equivalent yield.

However, application of 75% RDF + Vermicompost (5 t ha^{-1}) + Zn-EDTA Foliar Spray @ 0.5% to Groundnut + Foliar Spray to Pigeonpea (2% DAP & NAA 40 ppm) (T_5) registered the highest B: C ratio of 3.5. This might be due to increase in the yield of both the base crop and intercrop under integrated nutrient management and at the same time it would be capable of giving minimum fluctuation in yield when they subjected to uncertain and unfavourable seasonal condition. This result was in accordance with the finding of Ashutosh Barthwal *et al*. (2018). In addition, it also reduced the cost of external inputs, minimizes the labour requirement, effectively utilized the available resources and enhanced the economic produce which ultimately obtained the higher net return and B:C ratio. The integrated use of NPK, vermicompost and foliar nutrition are applied to any type of crops and it decreases the cost of cultivation which in turn reduces the amount of fertilizer thereby dipping the cost of crop production (Sivakumar *et al*. 2019) [35].

Table 1: Effect of INM on growth attributes of groundnut under groundnut + pigeonpea intercropping system

Treatments	Plant height (cm)	LAI (60 DAS)	No. of effective nodules/plant	DMP (Kg/ha)	CGR (g/m^2/day) 45 DAS-Harvest
T_1	26.62	2.93	56.39	3807	13.21
T_2	39.45	3.46	74.65	4734	13.78
T_3	41.88	3.54	77.78	4890	13.89
T_4	35.00	3.22	67.67	4449	13.59
T_5	52.53	4.16	95.28	5644	14.48
T_6	58.69	4.28	98.43	5814	14.65
T_7	47.99	3.80	83.26	5223	14.20
S.Em±	1.87	0.07	3.78	78	0.05
C. D. (P=0.05)	5.54	0.21	11.50	237	0.15

Table 2: Effect of INM on yield attributes and yield of groundnut under groundnut + pigeonpea intercropping system

Treatments	No. of pods/ plant	Shelling %*	Test weight (g)	Pod yield (kg/ha)	Kernel yield (kg/ha)	Haulm yield (kg/ha)
T_1	10.00	57.00 (49.02)	33.28	1198	898	2906
T_2	16.00	64.23 (53.28)	33.23	1501	1125	3483
T_3	16.21	64.35 (60.73)	34.15	1577	1182	3568
T_4	13.00	60.73 (51.19)	34.23	1366	1024	3265
T_5	24.31	72.13 (58.13)	34.91	1995	1496	4083
T_6	25.78	73.02 (58.70)	35.13	2087	1565	4138
T_7	19.36	67.87 (55.47)	34.68	1739	1304	3790
S.Em±	0.74	1.12	0.16	35	21	70
C. D. (P=0.05)	2.36	3.38	NS	107	62	207

*Values in parentheses are arcsine transformed values of percentages

Table 3: Effect of INM on quality parameters of groundnut under groundnut + pigeonpea intercropping system

Treatments	Oil content (%)*	Crude Protein (%)*	Kernal Zn content (mg/kg)
T_1	40.78 (39.68)	21.82 (27.84)	49.07
T_2	45.00 (42.12)	23.90 (29.26)	51.48
T_3	45.04 (42.15)	23.99 (29.31)	51.37
T_4	42.95 (40.94)	22.90 (28.59)	50.74
T_5	49.38 (44.64)	26.13 (30.74)	52.11
T_6	49.74 (44.85)	26.38 (30.90)	51.65
T_7	47.10 (43.33)	25.00 (29.99)	50.00
S.Em±	0.65	0.31	0.08
C. D. (P=0.05)	1.99	0.97	0.27

*Values in parentheses are arcsine transformed values of percentages

Table 4: Effect of INM on growth attributes of pigeonpea under groundnut + pigeonpea intercropping system

Treatments	Plant height (cm)	LAI (Maximum Flowering Stage)	DMP (Kg/ha)	CGR (g/m^2/day) 45 DAS – Harvest
T_1	165.70	2.08	2145	14.61
T_2	180.78	2.74	2820	18.69
T_3	188.00	2.87	2935	19.55
T_4	181.13	2.46	2624	17.11
T_5	211.59	3.64	3608	26.04
T_6	217.62	3.86	3790	26.12
T_7	198.45	3.21	3205	21.57
S.Em±	3.60	0.06	59	1.02
C. D. (P=0.05)	11.16	0.18	176	3.15

Table 5: Effect of INM on yield attributes and yield of pigeonpea under groundnut + pigeonpea intercropping system

Treatments	No. of pods/plant	No. of seeds/pod	Seed yield (kg/ha)	Stalk yield (kg/ha)
T_1	110	3.31	157	1982
T_2	160	3.87	330	2452
T_3	163	3.97	365	2517
T_4	131	3.65	262	2266
T_5	203	4.66	609	2981
T_6	208	4.68	658	3083
T_7	179	4.29	455	2702
S.Em±	2.6	0.07	14	68
C. D. (P=0.05)	8.2	0.21	45	197

Table 6: Effect of INM on groundnut equivalent yield (kg/ha) and B:C ratio under groundnut + pigeonpea intercropping system (*data statistically not analysed)

Treatments	Groundnut equivalent yield (kg/ha)	Return/rupee invested
T_1	314	1.85
T_2	660	2.58
T_3	730	2.70
T_4	524	2.17
T_5	1218	3.50
T_6	1316	3.42
T_7	910	2.68

Conclusion

Integrated nutrient management practices sustain plant productivity and soil fertility. It can be concluded that application of 100 percent RDF along with vermicompost (4 t ha^{-1}) to groundnut and foliar spray to pigeonpea (2% DAP and NAA 40 ppm) had a remarkable effect on growth, and. However, it was statistically comparable with the integrated application of 75 percent RDF (12.75: 25.5: 40.5 kg N, P_2O_5 and K_2O ha^{-1}) along with vermicompost (5 t ha^{-1}) to groundnut and foliar application to pigeonpea (2% DAP and NAA 40 ppm). It saves 25 percent NPK fertilizer and improved the productivity of groundnut + pigeonpea legume-legume intercropping system. Further, zinc application also increased the zinc concentration of kernels and this agronomical biofortification helps to alleviate malnutrition of rural farmers. It is also considered as a climate resilient best management practice because it reduces the environmental degradation caused by the excess application of fertilizers and the energy needed to its production.

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