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Performance, Uptake and Use Efficiency of Nutrients in Maize (*Zea mays* L.) and Mashbean (*Vigna mungo* L.) alongwith Microbiological Properties under Intercropping System in *Alluvial* Soil of India

Ashish Dwivedi[1]*, Adesh Singh[1], S. S. Tomar[1], Sudhir Kumar[2], Istya Dev[1], Roop Kishore[3] Prashant Singh[1] and Vineet Kumar[1]

[1]Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology,Meerut - 250110, India.
[2]Department of Entomology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut - 250110, India.
[3]Department of Agronomy, Doon (P.G.) College of Agric. Science & Technology (Affiliation - HNB Garhwal University), Deharadun - 248 001, India.

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At this moment in time, incessant cereal-cereal cropping with arbitrary use of fertilizers is pretense threat to rural sustainability and environmental security. Under such state of affairs crop diversification is the best options, which not only gives supplementary productivity but also ensure the rational use of the resources and resulted in substantial cutback of inputs. Therefore a make inquiries was undertaken to study Performance, uptake and used efficiency of nutrients in maize and mashbean along with microbiological properties under intercropping system during *kharif* season of 2012 in which two cropping system *viz*., maize+mashbean and maize alone, two planting geometries *viz*., normal and paired planting and three fertility levels control, 100% NPK and 100% NPK + Zn + PSB, replicated thrice in a two and three factor RBD by using F test. The data on growth and yield were calculated on net plot area basis (15 m^2), total uptake of nutrient and its used efficiency was recorded as per the standard procedure. The results revealed that growth; yield (40.46 kg ha^{-1}) and its production efficiency (46.51 kg day^{-1} ha^{-1}), crop growth rate (32.9 g m^{-2} day^{-2}) total uptake of N (92.41 kg ha^{-1}), P (20.72 kg ha^{-1}) and K (105.28), Nutrient used efficiency (N, P, K and Zn) and microbial population *viz*., bacteria (69.02 x10^5) and fungi (15.79 x10^2) significantly superior in maize+mashbean intercropping systems, though actinomycetes (15.78 x10^4) remained not significant than their sole cropping. Likewise, paired planting geometry recorded maximum above parameters in maize than 50 cm spacing, whereas, in mashbean reverse trends were observed. Moreover, fertility level of 100% NPK+Zn+PSB resulted into higher values of above mentioned parameters in both crop than their respective counterparts, except control in case of nutrient used efficiency which was remained skip.

Key words: Performance, Uptake, Nutrient used efficiency (N, P, K and Zn), Microbiological population, Maize+Mashbean, Intercropping, PSB, Planting spacing.

In India Maize is third most important cereal crop after rice and wheat. It occupies about 9.08 million ha area and produces 23.29 million tonnes of grains with an average productivity of 2563 kg/ha (Anonymous 2013-14). Indian pulse production has been stuck in between 14 and 15 million tonnes since mid-nineties, resulting in poor consumption (60g/day/capita in 1951 to 33g/day/person at present).

Cropping systems varies from place to place in the world. A good system is designed to improve it in a given agro ecological climate

* To whom all correspondence should be addressed.
E-mail: ashishdwivedi842@gmail.com

which is adapted by the farmers of the area in terms of their biological productivity and stability of production with the least harm to the ecosystem. Farmers generally take own decisions on the technologies to be adopted on the basis of cost, risk and return calculations. In small farms, the farmers raise crops as a risk minimizing measures against total crop failures and to get different produces to take of his family food, income, etc. moreover, benefits of intercropping may be briefed as, improvement of soil fertility by legume components of the system, soil preservation through covering the bare land between the rows, better use of resources, suppression of weeds infestation, reduction of biotic and abiotic risks by increasing diversity, etc. In intercropping system involving legume and non legume, legume may provide nitrogen benefiting non-legume component, which improve nitrogen uptake and fertility status (Dwivedi *et al*., 2015). India is the largest homeland of vegetarian population and world leader in pulse production which play vital role to provide protein supplements (Singh *et al*., 2007).

Growth yield attributes in maize and mashbean and nitrogen contents in mashbean only superior in intercropping with paired planting geometry than their sole cropping with other geometries (Dwivedi *et al*., 2015). Intercropping of maize with urdbean resulted in 9.7 to 11.5 per cent higher grain yield than sole maize grown with normal and paired spacing, respectively (Shivay and Singh, 2003). Moreover, N, P and K Uptakes by blackgram were higher in the sole planting as against (2:1) maize + blackgram intercropping system (Dwivedi *et al*., 2012). Although, there were 5.25 and 8.71% increase in population of bacteria with intercropping of peas as compared with sole sugarcane crop after a period of four weeks at site I and II respectively. Similarly, population of actinomycetes also increased under sugarcane and peas intercropping system. However fungal count did not vary under cropping systems Kaur *et al.* (2013). Therefore symbiotic nitrogen fixation becomes a good alternative for sustainable crop production in the majority of soils this is because it has been shown to increase nutrient use efficiency, increase nitrogen uptake, increase apparent nitrogen recovery and other benefits as subsequent crop Aggarwale *et al*. (2002).

The values of all nitrogen use efficiency (NUE) terms in western Uttar Pradesh in India were lower compared to the global. Additionally, values of all terms of NUE showing that in the experiment, N is more efficiently utilized for global than western Uttar Pradesh in India (Naresh *et al*., 2014). Therefore, the present study was carried out to evaluate performance, uptake and used efficiency of nutrients of maize and mashbean alongwith microbiological properties under intercropping system in alluvial soil.

MATARIALS AND METHOD

Experimental details and soil description

A field experiment was conducted during *kharif* season 2012 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), the area lie at a latitude of 29° 40' North and longitude of 77° 42' East with an elevation of 237 metres above mean sea level. The mean weekly maximum temperature was 39.2°C which was recorded in the last week of June. It was gradually decline and reached to minimum at the time of harvest of crops. Moreover, minimum temperature follows the same trend as of maximum temperature, though the lowest temperature was 18.1^{0}C during the third week of October. The mean weekly relative humidity at 7.00 and 14.00 hrs varied from 80.8 to 59.9 and 73.7 to 23 per cent, respectively. The total rainfall received during crop period was 651.6 mm. The experimental field was well drained, sandy loam in texture (46.2 % sand, 18.4 % silt and 17.4 % clay, Bouyoucos hydrometer method) and slightly alkaline in reaction (pH 7.8, Glass electrode pH meter). It was medium in organic carbon (0.570 %), available nitrogen (222.6 kg/ha) and available phosphorus (16.6 kg/ha) but high in available potassium (249.0 kg/ha) with an electrical conductivity (1:2, soil: water suspension, Solbridge conductivity meter method) and Bulk density (Core sampler method of 1.6 dS/m and 1.42 Mg/m3), respectively. All the physic-chemical properties were analyzed as per the slandered procedures given by Jackson (1973). The treatments comprised two cropping system *viz.*, maize+mashbean and maize alone,

two planting geometries *viz.*, normal and paired planting and three fertility levels control, 100% NPK and 100%NPK + Zn + PSB, replicated thrice in a factorial randomized block design. The crop was grown as per agronomic package of practice with varieties PAC 712 (Maize) and PU 19 (Mashbean) with the spacing (rows) of 50 cm (Normal) and 30/70 cm (Paired). The seeds were placed manually in the furrows at a plant to plant distance of 20 and 10 cm with a seed rate of 20 and 15 kg/ha for maize and mashbean, respectively and sown on 30 July 2012. The 100 per cent NPK (for maize) is characterized by 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ ha and Zn is applied @ 0.5% $ZnSO_4$ as spray whereas, PSB is used as seed treatment @ 20 g/kg of seed. Two hand weedings were done manually with the help of khurpi for controlling weeds, first at 25 days after sowing and second at 45 days after sowing,. The maize crop is highly sensitive to water excess and stress, therefore, surface drains were opened just after sowing to ensure proper drainage. Moreover, Only 1 irrigation was applied at 57 DAS due to rains commensurate well with crop water requirement at critical stages.

Data collection

Observations on various growth parameters viz. plant height (cm), plant spread (cm) and dry matter accumulation g/plant were recorded at 25 and 50 DAS in maize and 25 DAS in mashbean. Yield was estimated by the produce obtained from net plot area, treatment wise and finally expressed at 14 % moisture from 18 m^2, whereas Production efficiency of maize and mashbean was calculated by following formula (Kumawat *et al*., 2012).

$$PE = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Total duration taken crop (days)}}$$

Plant sampling and analysis

The total uptake of N, P and K was determined by plants which measured for yield was used for analyzing the N, P and K content in plant. The samples were dried at 70 °C in a hot air oven. The dried samples were ground in a stainless steel Thomas Model 4 Wiley ® Mill. The N content in plant was determined by digesting the samples in sulfuric acid (H2SO4), followed by analysis of total N by the Kjeldahl method (Page, 1982) using a Kjeltec™ 8000 auto analyzer (FOSS Company, Denmark). The P content in plant was determined by the vanadomolybdo-phosphoric yellow colour method and the K content was analyzed in di-acid (HNO3 and HClO4) digests by the flame photometeric method (Page, 1982). The uptake of the nutrients was calculated by multiplying the nutrient content (%) by respective yield (kg/ha^2) and was divided by 100 to get the uptake values in kg/ha^2. Finally the sum of grain and straw produce total uptake.

In general, four terms are used in relation to nutrient use efficiency (NUE). These are: agronomic efficiency (AE), recovery efficiency (RE), physiological efficiency (PE) and partial factor productivity of fertilizers (PFP). The following expression is used for determining these parameters (Naresh *et al*., 2014):

$AE = (Y - Y0) / F$

$PFP = Y / F = (Y0 / F) + AE$

$RE = (U - U0) / F$

$PE = (Y - Y0) / (U - U0)$

Where, *Y* is the yield of fertilized plot, *Y*0 is the yield of unfertilized plot, *F* is the quantity of fertilizer applied, *U* is nutrient uptake in fertilized crop, and *U*0 is nutrient uptake in unfertilized crop.

Soil sampling and analysis

Numbers of soil culturable bacteria, fungi and actinomycetes were counted at the maturity stage. Soil cores near the rice roots were collected with an auger. The top 1 cm soil layer was removed and the remaining soil core (as deep as 0.2 m) was sampled. After air-drying, samples were sieved through a 1-mm sieve. Ten grams of each fresh soil sample was added to 95 ml of sterile distilled water. After homogenization for 30 min, each soil suspension was sequentially diluted and 50 µL of the resulting solutions were placed on appropriate isolation culture media. After incubation at 28°C for 4–5 days for bacteria, 3–4 days for fungi and 6–8 days for actinomycetes or 6–9 days, the colony forming units (CFU) were counted. Soil bacteria, fungi and actinomycetes were cultured on beef extract + peptone + agar medium, Martin medium, improved Gauss No. 1 medium, and Waksman No. 77 medium (Vieira and Nahas 2005), respectively.

The data obtained were subjected to statistical analysis as outlined by Gomez and

Table 1. Growth, crop, growth rate, yield and production efficiency of maize as influenced by various treatments

Treatment	Plant height (cm)		Plant spread (cm)		Dry matter (g/plant)		CGR	Grain yield	Production
	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	(g m^{-2} day^{-2})	(q/ha)	efficiency
Cropping systems									
Sole maize	48.0	135.9	39.3	78.5	9.7	16.2	39.2	38.89	44.70
Maize+Mashbean	57.3	148.2	48.0	80.9	13.9	22.6	32.9	40.46	46.51
S.Em.±	0.2	0.7	0.4	0.5	0.2	0.2	0.1	0.19	0.22
C.D. (P=0.05)	0.7	2.1	1.1	1.4	0.5	0.6	0.3	0.56	0.64
Planting geometries									
Normal (50 cm)	49.9	154.4	42.6	83.3	11.7	19.1	40.7	39.45	45.34
Paired (30/70 cm)	55.4	129.8	44.8	76.1	12.0	19.7	31.3	39.90	45.86
S.Em.±	0.2	0.7	0.4	0.5	0.2	0.2	0.1	0.19	0.22
C.D. (P=0.05)	0.7	2.1	1.1	1.4	NS	0.6	0.3	NS	NS
Fertility levels									
Control	45.1	114.7	32.6	72.4	7.1	13.5	39.8	32.01	36.79
100% NPK	53.2	147.1	46.2	80.2	12.4	20.2	34	43.15	49.60
100% NPK+Zn+PSB	59.7	164.4	52.1	86.5	16.0	24.5	34.4	43.82	50.37
S.Em.±	0.3	0.9	0.4	0.6	0.2	0.2	0.2	0.23	0.26
C.D. (P=0.05)	0.9	2.6	1.3	1.7	0.6	0.7	0.4	0.68	0.78

Gomez (1984). The treatment differences were tested by using "F" test and critical differences (at 5 per cent probability).

RESULTS AND DISCUSSION

Growth parameters of maize

Growth values of maize increase with advancement in crop age and reached to maximum at 50 DAS (Table 1). Growth values varied significantly due to cropping system, planting geometries and fertility levels at all the stages of crop growth. Maize + mashbean intercropping resulted significantly tallest plant (48.0 and 135.9 cm), horizontal spread (39.3 and 78.5 cm) and dry weight (9.7 and16.2g) than their sole cropping at 25 and 75 DAS, respectively. Although, significantly higher plant height (49.9 cm) and plant spread (42.6 cm) under normal planting as compared to paired planting at only 25 DAS, whereas, at 50 DAS normal planting noticed higher plant height and plant spread. Moreover, dry matter accumulation was increased with (30/70 cm) planting arrangements. However, the use of 100% NPK + Zn + PSB noticed tallest plant, plant spread and dry matter accumulation as compared to control and recommended 100% NPK alone during both the stages. The increased values of growth might be due to better resource utilization along with fact that intercropped mashbean will fix nitrogen from atmosphere which might be utilized by the maize. Similar observations were also reported by Sadashiv (2004), Pathak and Singh (2006) and Tripathi *et al.* (2008).

Crop growth rate (CGR) of maize

Intercropping system recorded significantly lower CGR (32.9 g m^{-2} day^{-2}) than sole cropping (39.2 g m^{-2} day^{-2}) **(Table 1)**. Moreover, normal geometries noticed significantly maximum CGR (40.7 g m^{-2} day^{-2}) as compared to paired planting (31.3 g m^{-2} day^{-2}). Significantly higher CGR was noticed by the combined use of 100% NPK +Zn + PSB than 100% NPK and control. This might be due to over shedding and legume affect which in turn to make significant variation.

Yield and production efficiency of maize

Intercropping system was recorded significantly higher grain (4.0 % ha^{-1}) as well as production efficiency (3.9 % kg day^{-1} ha^{-1}) than

their sole stands (Table 1). Moreover, grain yield and production efficiency remained *on par* under both the row ratio. Yield and production efficiency varied significantly due to each increment in fertility levels, except grain yield and production efficiency which remained *on par* between 100% NPK and 100% NPK+Zn+PSB treatments. It might be due to better translocation of source towards sink which were even influenced by more dry weight assimilation which resulted more production efficiency. Our results were also supported by Padhi and Panigrahi (2006) and Jeyakumaran and Seran (2007).

Total nutrient uptake of maize

Under cropping system, intercropping system recorded significantly higher total uptake of nitrogen and the improvement was to tune of 2.5 per cent, respectively than sole cropping (Table 2), whereas the total uptake of phosphorus was dropped by 2.7 per cent in sole cropping. Between planting geometries, significantly (1.6 and 4.5 per cent) higher phosphorus and

Table 2. Total uptake of nutrients of maize as influenced by various treatments

Treatment	Total nitrogen uptake (kg ha^{-1})	Total phosphorus uptake (kg ha^{-1})	Total potassium uptake (kg ha^{-1})
Cropping systems			
Sole maize	90.16	20.16	101.92
Maize+Mashbean	92.41	20.72	105.28
S.Em.±	0.56	0.11	0.56
C.D. (P=0.05)	2.24	0.32	1.12
Planting geometries			
Normal (50 cm)	90.16	20.16	107.52
Paired (30/70 cm)	91.84	20.72	100.24
S.Em.±	0.56	0.11	0.56
C.D. (P=0.05)	NS	0.32	1.12
Fertility levels			
Control	73.92	16.24	86.24
100% NPK	98.00	21.84	109.76
100% NPK+Zn+PSB	101.00	23.52	115.36
S.Em.±	1.12	0.13	0.56
C.D. (P=0.05)	2.24	0.40	1.68

Table 3. Microbial population of maize as influenced by various treatments

Treatment	Bacteria (CFU)	Fungus (CFU)	Actinomycetes (CFU)
Cropping systems			
Sole maize	63.45×10^5	15.46×10^2	22.46×10^4
Maize+Mashbean	69.02×10^5	15.79×10^2	15.78×10^4
S.Em.±	0.015	0.018	4.96
C.D. (P=0.05)	0.044	0.053	NS
Planting geometries			
Normal (50 cm)	70.39×10^5	15.98×10^2	15.98×10^4
Paired (30/70 cm)	62.08×10^5	15.26×10^2	22.26×10^4
S.Em.±	0.015	0.018	4.96
C.D. (P=0.05)	0.044	0.053	NS
Fertility levels			
Control	43.90×10^5	14.63×10^2	25.13×10^4
100% NPK	72.67×10^5	15.42×10^2	16.81×10^4
100% NPK+Zn+PSB	82.12×10^5	16.81×10^2	15.42×10^4
S.Em.±	0.018	0.022	6.0
C.D. (P=0.05)	0.054	0.064	NS

potassium uptake, respectively was noticed under paired planting (30/70 cm) as compared to normal planting, however the difference was non-significant in total uptake of nitrogen. Significantly higher total uptake of nutrients was noticed by the combined use of 100% NPK +Zn + PSB and the improvement was to tune of 6.3 and 36.6, 7.7 and 44.8 and 5.1 and 33.8 per cent than 100% NPK and control, respectively. This might be due to delay in maturity of maize at the highest fertility level could tap up more nutrients for a longer period of time which consequent into higher uptake at higher fertility level. Similar results were also reported by Singh *et al*. (2007).

Microbial population

Microbial population varied significantly due to cropping system, planting geometries and fertility levels **(Table 3)**, except actinomycetes which remained not significant in all level. Maize + mashbean are intercropping resulted significantly maximum bacteria (69.02 x10^5 CFU) and fungi (15.79 x10^2 CFU) than their sole cropping, while actinomycetes shown irreversible trends and remained maximum in maize alone (22.46 x10^4 CFU). Although, significantly higher maximum bacteria (70.39 x10^5 CFU) and fungi (15.98 x10^2 CFU) and minimum actinomycetes (15.98 x10^4 CFU) were under normal planting as compared to paired planting, However, the use of 100% NPK + Zn + PSB noticed bacteria (82.12 x10^5 CFU) and fungi (16.81 x10^2 CFU) as compared to control and recommended 100% NPK alone. This may be due to availability of more organic matter or plant biomass for their food and energy in inorganic or

Table 4. Growth, crop growth rate, yield and production efficiency of mashbean as influenced by various treatments

Treatment	Plant height (cm)	Plant spread (cm)	Dry matter (g/plant)	CGR (g m^{-2} day^{-2})	Grain yield (q/ha)	Production efficiency
Planting geometries						
Normal (50 cm)	25.4	19.1	2.3	7.0	5.42	7.01
Paired (30/70 cm)	23.0	18.0	2.3	4.9	4.81	5.84
S.Em.±	0.2	0.4	0.1	0.1	0.1	0.13
C.D. (P=0.05)	0.7	1.2	NS	NS	0.3	0.39
Fertility levels						
Control	21.0	15.0	2.0	2.9	4.54	6.23
100% NPK	24.6	19.1	2.4	5.7	5.02	6.49
100% NPK+Zn+PSB	26.9	21.5	2.6	7.6	5.33	6.88
S.Em.±	0.3	0.5	0.1	0.1	0.1	0.13
C.D. (P=0.05)	0.8	1.4	0.4	0.4	0.3	0.39

combine use of fertilizers treated plots **Kaur *et al.* (2013)**. The actinomycetes population was increase substantially with decrease population of bacteria and fungi and reached to maximum under control plot (25.13 x10^4 CFU). This may be due to poor availability of lignin like compound for the food and energy for actinomycetes sunder other treatments as compare to control. The results were in consonance with the findings of **Tilak (2004)**.

Nutrients used efficiency (N, P, K and Zn) of maize

Nitrogen use efficiency (NiUE)

The values of all nitrogen use efficiency (NiUE) terms in western Uttar Pradesh in India were lower compared to the global. Additionally, values of all terms of NiUE in the experiment showing that, N is more efficiently utilized in global than western Uttar Pradesh in India. Thus, in western Uttar Pradesh, there is a considerable scope to increase NiUE. Though, a computation of values present in Figure 1 revealed that the intercropping of maize+mashbean recorded NiUE *viz.*, maximum agronomic efficiency (7.04 kg/ha), partial factor productivity (33.72), recovery efficiency (15.41 %) and physiological efficiency (45.70) than sole cropping (5.73 kg/ha, 32.41, 13.53 % and 42.36, respectively). Moreover, normal geometries noticed lower agronomic efficiency (6.20 kg/ha), partial factor productivity (32.88), recovery efficiency (13.53 %) and physiological efficiency (45.81) as compared to

paired planting. Application of Zn and PSB along with recommended 100% NPK was recorded maximum agronomic efficiency (9.84 kg/ha), partial factor productivity (36.52), recovery efficiency (22.57 %) and physiological efficiency (43.61) than 100% NPK alone (9.28 kg/ha, 35.96, 20.07 % and 46.26, respectively). This finding corroborates with the report by Umeh *et al.* (2012) and Aggarwale *et al.* (2002) that intercropping with legumes complement soil-nitrogen, increases nitrogen use efficiency, nitrogen uptake, apparent nitrogen recovery and other benefits as companion crop or subsequent crop.

Phosphorus use efficiency (PUE)

The values of all phosphorus use efficiency (PUE) terms in India were far lower as compared to some developed country. Besides, PUE in the experiment of western U.P. showed that, P is more efficiently utilized in some country like USA. Japan, Israel etc. than India. So there is a significant scope to increase PUE. Though, a computation of values present in **Figure 2** revealed that the intercropping of maize+mashbean recorded maximum PUE *viz.*, agronomic efficiency (14.08 kg/ha), partial factor productivity (67.43), recovery efficiency (7.47 %) and physiological efficiency (188.62) than their sole stands (11.47 kg/ha, 64.82, 6.53 % and 175.51, respectively). Moreover, 70/30 cm spacing recorded higher agronomic efficiency (13.15 kg/ha), partial factor productivity (66.50), recovery efficiency (7.47 %) and physiological efficiency (176.12) as compared to 50 cm spacing. Application of Zn and PSB along with recommended 100% NPK was recorded maximum agronomic efficiency (19.68 kg/ha), partial factor productivity (73.03), recovery efficiency (12.13 %) and physiological efficiency (162.23) than 100% NPK alone. This might be due to application of PSB along with full dose of

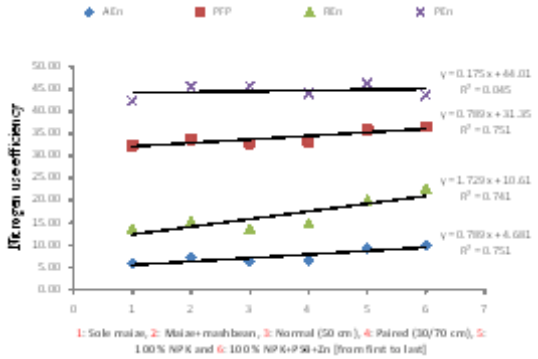

Fig. 1. Relationship between above treatments on Agronomic efficiency (AEn), Partial factor Productivity (PFP), Recovery Efficiency (REn) and Physiological efficiency (PEn) of Nitrogen in Maize

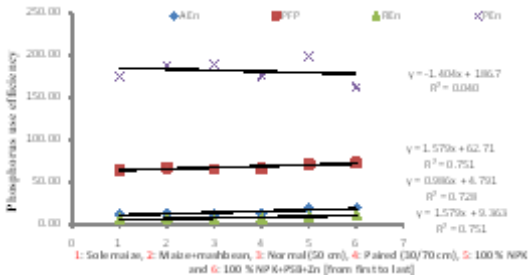

Fig. 2. Relationship between above treatments on Agronomic efficiency (AEn), Partial factor Productivity (PFP), Recovery Efficiency (REn) and Physiological efficiency (PEn) of Phosphorus in Maize

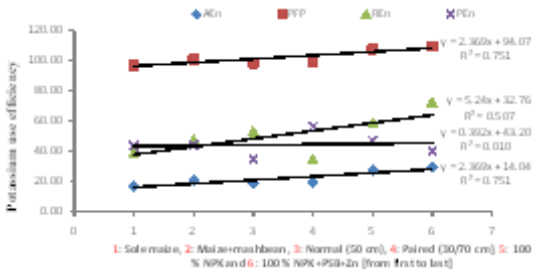

Fig. 3. Relationship between above treatments on Agronomic efficiency (AEn), Partial factor Productivity (PFP), Recovery Efficiency (REn) and Physiological efficiency (PEn) of Potassium in Maize

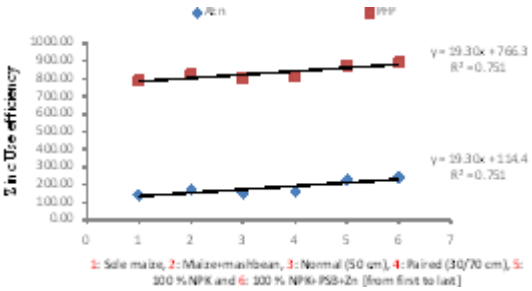

Fig. 4. Relationship between above treatments on Agronomic efficiency (AEn) and Partial factor Productivity (PFP) of Zinc in Maize

phosphorus resulted to increased Phosphorus use efficiency Our results were also supported by IITA (2014) and Khan *et al.* (2010)

Potassium use efficiency (KUE)

The data present in **Figure 3** revealed that among cropping system, intercropping system maintain its superiority over sole cropping in terms of agronomic efficiency (21.13 kg/ha), partial factor productivity (101.15), recovery efficiency (47.60 %) and physiological efficiency (44.38) of KUE whereas, normal geometries noticed lower KUE *viz.*, agronomic efficiency (18.60 kg/ha), partial factor productivity (98.63), recovery efficiency (53.20 %) and physiological efficiency (34.96) as compared to paired planting. While at fertility level Higher KUE was noticed by the combined use of 100% NPK +Zn + PSB than 100% NPK. The probable reason was that the intercropping utilized potassium more efficiently than their sole stand. Our results were also supported by IITA (2014)

Zinc used efficiency (ZnUE)

Maize alone (Figure 4) recorded far lowest values of ZnUE terms *viz.*, agronomic efficiency (140.12 kg/ha), partial factor productivity (792.06) as compared to intercropping system. Whereas, a slight variation was observed in planting geometry, in which paired planting recorded highest agronomic efficiency (160.69 kg/ha), partial factor productivity (812.63). Likewise, combine used of 100 % NPK+ Zn + PSB noticed maximum above term than their respective counterpart.

Growth of mashbean

Normal planting noticed significantly higher growth attributes of mashbean at 25 DAS *viz.*, plant height (25.4 cm), plant spread (19.1 cm) and dry weight (2.36 g) than 70/30 spacing (23.0 cm, 18.0 cm and 2.30 g, respectively) (Table 4). However, the combine use of 100% NPK + Zn + PSB registered the tallest plant (26.9 cm), plant spread (21.5 cm) and dry weight (2.6 g) than 100% NPK alone, whereas, the minimum under untreated plot (21.0 cm, 15.0 cm and 2.0 g, respectively). The probable reason is to more penetration of light and efficient utilization of resources than 70/30 row ratio of mashbean. Similar opinion was also put forward by Pathak and Singh (2006). The proportion of protoplasm to cell wall material is increased by nitrogen and had various consequences, one of them being an increase in cell size, which expressed morphologically increased in height of plant and dry weight, (Arnon, 1953).

Crop growth rate (CGR) of mashbean

50 cm spacing noticed significantly maximum CGR (7.0 g m^{-2} day^{-2}) as compared to pair planting (4.9 g m^{-2} day^{-2}) (Table 4). Moreover, significantly higher CGR was noticed by the combined use of 100% NPK +Zn + PSB (7.6 g m^{-2} day^{-2}) than 100% NPK and control. This might be due to over shedding and legume affect which in turn to make significant variation.

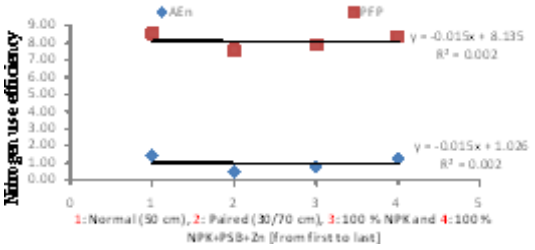

Fig. 5. Relationship between above treatments on Agronomic efficiency (AEn) and Partial factor Productivity (PFP) of Nitrogen in Mashbean

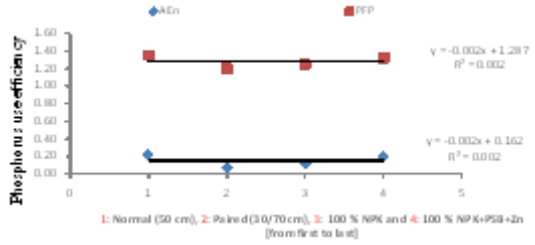

Fig. 6. Relationship between above treatments on Agronomic efficiency (AEn) and Partial factor Productivity (PFP) of Phosphorus in Mashbean

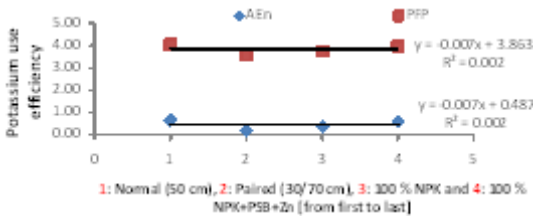

Fig. 7. Relationship between above treatments on Agronomic efficiency (AEn) and Partial factor Productivity (PFP) of Potassium in Mashbean

Yield and production efficiency of mashbean

Normal planting registered significantly more grain per hectare and production efficiency as compared to paired planting and the improvement was to the tune of 20.0 % and 10.2 %, respectively (Table 4). Grain yields per hectare and production efficiency were increased by increasing levels of fertility and reached maximum up to 100 % NPK + Zn + PSB. The higher yield was might be due to higher dry matter accumulation and also more translocation of photosynthates toward its used which resulted more production efficiency. Similar finding were also reported by Ghosh *et al*. (2006) and Seran and Brintha (2009).

Nutrients use efficiency (N, P and K) of mashbean

In India the efficiency of NPK in legume is far lowered as compared to world agriculture and this was come lower in intercropping than their sole one (Figure 5, 6, 7). Moreover, paired planting recorded highest N, P and K used efficiencies *viz.*, agronomic efficiency 1.42, 0.23 and 0.68 kg/ha and partial factor productivity 8.53, 1.35 and 4.05, respectively as compared to normal planting. Likewise, application of Zn and PSB along with recommended 100% NPK was recorded maximum agronomic efficiency (1.26, 0.20 and 0.60 kg/ha) and partial factor productivity (8.37, 1.33 and 3.98) of N, P and K, respectively as compared to 100 % NPK. This finding corroborates with the report by Aggarwale *et al*. (2002) that intercropping with legumes complement soil-nitrogen, increases nitrogen use efficiency and apparent nitrogen recovery.

CONCLUSION

The above study show that maize+mashbean intercropping under paired/ normal planting proved to be better out yield of growth parameters, yield and its production efficiency, microbial population *viz.*, bacteria and fungi, total Nitrogen, Phosphorus and Potassium uptake and its used efficiency terms like agronomic efficiency, partial factor productivity, recovery efficiency and physiological efficiency of maize and mashbean when fertilized with 100% NPK along with application of Zn and PSB. Though, it minimized actinomycetes population considerably at highly fertilized plot.

REFERENCES

1. Aggarwal PK, Qarrity OP, Liboon SP, Morris RA. Resource use and plant interaction in a rice-mugbean intercrop. *Agro J*, 2002; **84**: 71-78.
2. Anonymous. (2013-14). Agricultural statistics at a glance, Ministry of Agriculture. pp.46-53. *www.cimmet.nic.in*. Accessed on September 29, 2014.
3. Arnon I. The physiology and biochemistry of phosphorus in green plants. *Agron. Monogram*, 1953; **4**: 10.
4. Dwivedi, A., Singh, A., Kumar, V., Naresh, R.K., Tomar S.S. and Dev, I. Population studies, phenology and quality of mashbean and maize as influenced by planting geometry and nutrient management under intercropping system, *Prog. Agric*, 2015; **15** (1): 95-98.
5. Dwivedi, SK, Shrivastava GK, Shrivatava A. Nodulation, nutrient uptake and yield of maize+blackgram intercropping system in *Vertisols* under rainfed condition. *Current Adv. Agri. Sci*, 2012; **4**: (2) 139-143.
6. Ghosh PK, Mohanty M, Bandyopadhyay KK, Painuli DK, Misra AK. Growth, competition, yields advantage and economics in soybean/ pigeonpea intercropping system in semi-arid tropics of India: II. Effect of nutrient management. *Field Crops Res*, 2006; **96**: (1) 90-97.
7. Gomez KA, Gomez AA. Statistical procedure for Agricultural Research An international Rice Research Institute Book. John Willey and sons, 2nd edition, 1984; 329.
8. International Institute of Tropical Agriculture (IITA) Annual Report. Restoring nutrients to sub-Saharan soils 2014.
9. Jackson ML**.** Soil Chemical Analysis. Prentice Hall Inc., Englewood. *Cliffs*, 1973; U. S. A.
10. Jeyakumaran J, Seran TH. Studies on intercropping capsicum (*Capsicum annum* L.) with bushitao (*Vigna unguiculata* L.). Proceedings of the 6th *Annual Res* 2007.
11. Kaur,N. Bhullar, M.S. Phutela, R.P. and Mahal, A.K. Soil Microbial Communities as Influenced by Intercropping and Herbicide Application in Autumn Sugarcane. *Journal of Pure and Applied Microbiology*, 2013; **8**: (3), 71-75
12. Khan JA, Banday AA, Zia-ul-Hassan. Effect of biofertilizers (PSB, *Azatobactor* and their combination) on seed germination of *Phaseolus aureus* Roxb. variety *Radiatus* (mung/green gram). *National J. Life Sci*, 2010; **7**: (2) 169-170.
13. Kumawat, N., Singh, R.P., Kumar, R., Kumari, A. and Kumar, P. Response of intercropping

and integrated nutrition on production potential and profitability on rainfed pigeonpea. *J. Agril. Sci*., 2012; **4**(7): 154-162.

14. Padhi AK, Panigrahi RK. Effect of intercrop and crop geometry on productivity, economics, energetics and soil-fertility status of maize (*Zea mays*)-based intercropping systems. *Ind. J. Agron*, 2006; **51**: (3) 174-177.
15. Page A L. Methods of Soil Analysis: Part 2. Chemical and Microbiological Properties. American Society of Agronomy, Soil Science Society of America, 1982; Madison, WI, USA.
16. Pathak K, Singh NP, Genotypic compatibility and planting pattern in urdbean and maize intercropping system. *Ind. J. Pulses Res*, 2006; **19**: (1) 116-118.
17. R. K. Naresh, S. S. Tomar, Dipender KUMAR, Samsher, Purushottam, S. P. Singh, Ashish Dwivedi, Vineet Kumar . Experiences with Rice Grown on Permanent Raised Beds: Effect of Crop Establishment Techniques on Water Use, Productivity, Profitability and Soil Physical Properties. *Rice Science*, 2014, **21**(3): 170"180.
18. Sadashiv BN. Production potential of hybrid cotton (*Gossypium hirsutum*) based vegetable intercropping systems under irrigation. M.Sc. Thesis, University of Agricultural Sciences, Dharwad, India.
19. Seran TH, Brintha I. Studies on determining a suitable pattern of capsicum (*Capsicum annum* L.)-vegetable cowpea (*Vigna unguiculata* L.) intercropping. *Karnataka J. Agric. Sci*, 2009; **22**: 1153-1154.
20. Shivay, Y. S. and Singh, R. P. Effect of nitrogen levels on productivity of grain legumes intercropped with maize (*Zea mays*). *Legume Res*, 2003; **26**(4): 303-306.
21. Singh, A. K., Roy, A. K. and Kaur, D. P. Effect of irrigation and NPK on nutrient uptake pattern and qualitative parameter in winter maize+potato intercropping system. *International Journal of Agriculture Science*, 2007; **3**: (1) 199-201.
22. TILAK, K. V. B. R., Response of *Sesbania* green manuring and mungbean residue incorporation on microbial activities for sustainability of a rice-wheat cropping system. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 2004; **105** (2): 189-196.
23. Tripathi AK, Dubey A P, Awasthi UD, Tripathi BN, Somendranath. Growth and dry-matter partitioning of winter maize (*Zea mays*) as influenced by intercropping. *Current Adv. Agric. Sci*, 2008; **4**(1): 20-24.
24. Umeh, S. I., Eze S. C., Eze E. I. and Ameh G. I. Nitrogen fertilization and use efficiency in an intercrop system of cassava (*Manihot esculent*a Crantz) and soybean (*Glycine max* (L) Meril.) *African Journal of Biotechnology*, 2012; **11**(41), pp. 9753-9757.
25. Vieira F.C.S., Nahas E. Comparison of microbial numbers in soils by using various culture media and temperatures. *Mi-crobiological Research*, 2005; **160**: 197–202.