Research Article

Productivity and Land Use Efficiency of Maize Mungbean Intercropping under Different Fertility Treatments

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Abstract | A trial was carried out to assess the efficacy of maize + mungbean intercropping systems under different fertility treatments at National Agriculture Research Centre (NARC) Islamabad, Pakistan. Cropping systems were kept in vertical blocks and fertility treatments in horizontal blocks replicated thrice with RCBD strip block system. Sole mungbean and intercropped mungbean with maize were treated with five fertility treatments (T1, control; Phosphorus and Potash (PK) (80-60 kg ha^{-1}) + inoculation, T3, (120-80-60 NPK kg ha^{-1}); T4, poultry manure (PM) @ 15 t ha^{-1} and half PM+ half PK+ inoculation, half poultry manure (7.5 t ha^{-1}) + half PK (40-30 kg ha^{-1}) + inoculation. According to statistical analysis, data revealed that plots treated with PK + inoculation with Rhizobium gave 33% higher mungbean seed yield over control. Similarly, higher values for yield contributing factors were also recorded in PK+ inoculation with Rhizobium. Partial land equivalent ratio (LER) of intercropped maize was 0.96 than respective sole crop. Maximum partial LER of mungbean (0.70) was recorded in intercropping systems. Total LER in maize + mungbean intercropping systems was 1.66 which indicates that 66 % more area would be required to attain same yield from respective sole cropping systems. Likewise, in fertility treatments total land equivalent ratio (1.78) was recorded in PK + inoculation treatment. It means that 78% more area would be required to achieve similar grain yield from control plots. Due to intercropping of legumes in maize and with application of poultry manure improved the organic matter and nutrients of soil.

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Introduction

Intercropping is the simultaneous growing of more than one species in the same field to rise per unit productivity per unit time. Cereal-legume intercropping is practiced in tropical regions (Hauggaard-Nielsen et al., 2001) and rain-fed tracts of the globe (Dhima et al., 2007; Agegnehu et al., 2006). According to Lichtfouse et al. (2010) decreased biodiversity due to monocropping is leading scientists to explore diverse cropping systems for increasing diversity. Intercropping is being considered to utilize these resources in an efficient way and is also most economical way to increase production per unit area and per unit time. The land equivalent ratio (LER) is a tool for calculating the cropping advantage of intercrops over sole crops is simple, ignoring weed inhibition, yield reliability, grain quality, and minimum advantageous yield are all relevant factors for farmers' perspective. The main reasons for smallholder farmers to practice

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intercrop are risk minimization, profit maximization, flexibility, improvement of soil fertility and soil conservation, pests and diseases control and balanced nutrition (Matusso et al., 2014).

Maize (*Zea mays* L.) is a major cereal crop; it contributes to GDP 0.5 % efficiently. Maize crop was grown on an area of 1.085 million hectares in 2013 which is 0.2 % less then over previous year. However, the production of maize crop was increased up to 4631 thousand tonnes over the last year (GOP, 2013). Mungbean (*Vigana radiata* L.) is an important pulse crop conventionally grown in Pakistan and commonly known as green gram. In Pakistan mungbean was grown on an area 136.1 thousands hectares in 2013 with annual seed production of 89.3 thousand tones. Mungbean is a potential crop and can produce a higher seed yield from 1295 to 2961 kg ha^{-1} the yield varies due to the subjected genotypes (Ullah et al., 2011).

The most important characteristic of mungbean crop is its ability of biological nitrogen fixation in root nodules by a symbiotic relationship with a specific bacterium that fulfill the crop needs for nitrogen (Mahmood and Athar, 2008; Mandal et al., 2009), it was also observed that the intercropping of maize with mungbean increased the total system productivity. Cereal-legume intercropping plays significant role in subsistence food production systems in both developed and developing countries (Tsubo et al., 2005).

The use of organic materials as fertilizers for producing crops has received a lot of attention for more sustainable crop productivity (Tejada et al., 2009), these organic materials is an excellent source of different nutrients and has ability to improve the soil characteristics (Moller, 2009). Biofertilizers are low cost, environmentally safe and non-bulky agricultural inputs as a supplementary and complementary factor to mineral nutrition. Rhizobium strains enhance nodulation in the host plant component. Phosphorus is a vital macro nutrient for determining the yield of legumes (Chaudhary, 2008). Phosphorous availability can be increased by mixing with farm yard manure (Hussain et al., 2008). Under such conditions complementary use of organic and inorganic fertilizers for crop production seems more productive and sustainable. Integrated use of inorganic and organic fertilizers surely enhanced the health of the soil and its fertility (Satyanarayana et al., 2002).

This paper highlights the productivity and land use efficiency of maize + mungbean intercropping systems under different fertility treatments under rained conditions of Potowhar tract.

Materials and Methods

A trial was conducted under rain fed conditions for two consecutive years (2007 and 2008) in the experimental area, National Agriculture Research Centre (NARC) Islamabad. The site lies in a subtropical, sub humid continental highland climatic zone characterized by long summers and cold winters. Data for rainfall and relative humidity is given in (Figure 1 and 2).

Soil samples were taken using auger from a depth of 0–30 cm at the start of the experiment. The soil of experimental area is sandy clay loam. The following chemical analyses were done on soil samples and poultry manure, using standard laboratory methods: soil *p*H, total nitrogen, electrical conductivity, available P. Particle size analysis and bulk density as physical properties were determined of the soil. Salicylic acid method was used for determination of NO_3- Nitrogen. Organic matter was also determined (Table 1).

Table 1: *Physio-chemical analyses of the soil samples from experimental site*

Soil Properties	Values
ECe	0.25 dS m^{-1}
pH	8.25
Organic matter	0.63 %
Sand	62 %
Silt	12 %
Clay	26 %
Textural class	Sandy-clay loam
Bulk density	1.47 g cm^{-3}
Available P	6.75 mg kg^{-1}
Extractable K	74.31 mg kg^{-1}
Nitrate-N	3.85 mg kg^{-1}
Total N	0.032 %

A complete randomized block design with strip split plot arrangement replicated thrice. Cropping systems were kept in vertical blocks and fertility treatments in horizontal blocks. Sole mungbean and intercropped mungbean with maize were treated with five fertility treatments (T1, control; T2, Phosphorus and Potash (PK) (80-60 kg ha^{-1}) + inoculation, T3, (120-80-60 NPK kg ha^{-1}); T4, poultry manure (PM) @ 15 t ha^{-1}

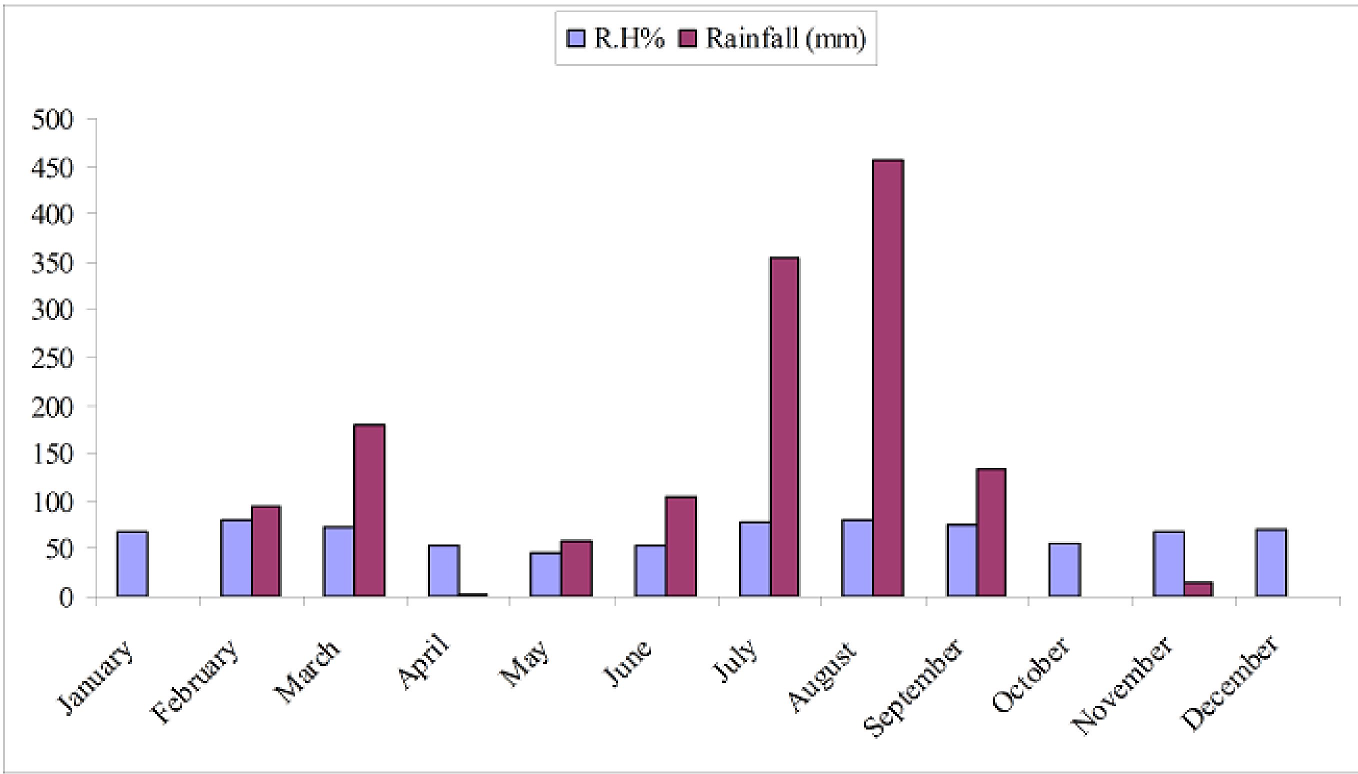

Figure 1: *Rainfall and relative humidity data during growing season (2007)*

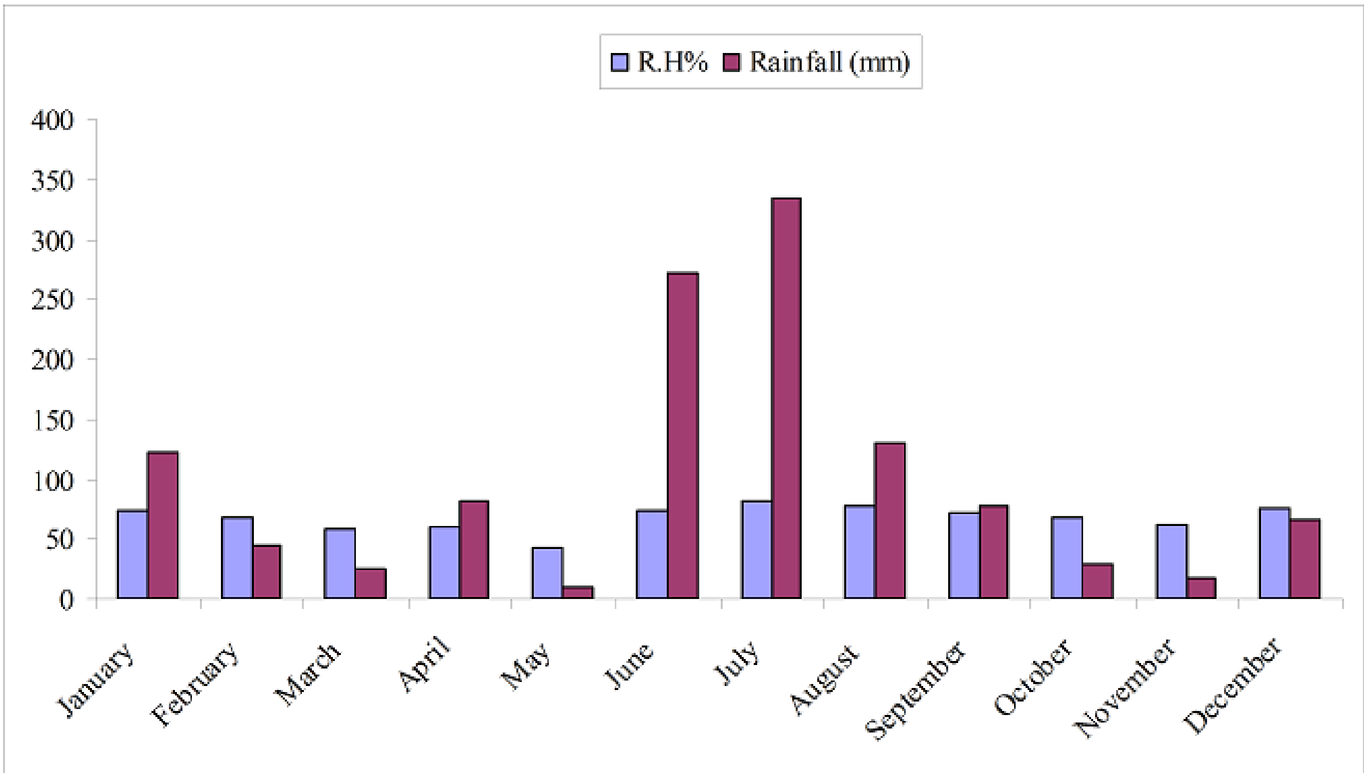

Figure 2: *Rainfall and relative humidity data during growing season (2008)*

and, T5, half poultry manure (7.5 t ha^{-1}) + half PK (40-30 kg ha^{-1}) + inoculation. Rhizobium was obtained from soil microbiology section, National Agriculture Research Centre (NARC) Islamabad. For inoculation of seeds 10% pure sugar solution was prepared and seeds were dipped into the inoculums may stick over the seeds. Seeds of mungbean were inoculated with Rhizobium strain TAL 169. Maize seed was inoculated Plant Growth Promoting Rhizobacteria. Inoculated seeds were dried under shade and used for the sowing in the respective plots.

Full dose of inorganic fertilizer PK (80:60 kg ha^{-1}); half dose of PK (40:30 kg ha^{-1}) and half dose of N were applied at sowing, while remaining half N was applied at respective critical stage. Maize variety Islamabad Gold was planted keeping row to row distance of 90 cm while mungbean (*Vigna radiata*) cultivar Chakwal Mung 97 was sown at 30 cm row to row in intercropping system and at 45 cm row to row distance in sole legumes on July 20, 2007 and July 25, 2008. After germination of seeds, plant spacing was maintained 20 cm, 10 cm and 15 cm by thinning two week after planting in order to achieve proper plant density in maize, in sole legumes and in intercropped legumes, respectively. All the crops were kept free of weed infestation by employing manual hoeing whenever required.

All other agronomic practices were kept normal and uniform for all the treatments. The maize and legume were harvested at maturity. Data regarding grain yield, biological yield, harvest index % and 1000-grain weight were recorded. Harvest index (HI%) values were calculated by using the formula:

$$HI\% = Grain\ yield / Biological\ yield \times 100 \quad (1)$$

Total Land Equivalent Ratio (LER_T) was calculated including maize partial LER (LER_M) and bean partial LER (LER_b) was calculated as follows:

$$LERT = LER_M + LER_B = Y^{IM}/Y_{SM} + Y^{IB}/Y_{SB} \quad (2)$$

Where: Y^{IM} and Y^{IB} are mass yields per unit area of intercropped maize kernels and bean seeds respectively, and Y_{SM} and Y_{SB} are mass yield per unit area of sole cropped maize kernels and bean seeds respectively.

Data recorded on various aspects were subjected to statistical analysis and treatment means was compared using Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984) by employing STAT package (Freed and Eisensmith, 1986).

Results and Discussion

Seed yield of mungbean varied significantly in different cropping systems and fertility treatments; however, their interactions were found non-significant (Table 2). Higher seed yield of mungbean (1292 kg ha^{-1}) was recorded in plots treated with PK + inoculation followed by half PM + half PK + inoculation with the yield of 1200 kg ha^{-1}. NPK and poultry manure application showed statistically at par yield of (1131 kg ha^{-1}) and (1087 kg ha^{-1}), respectively. Lower seed yield (871 kg ha^{-1}) was recorded in control treatments. Year as a source of variation significantly affected seed yield of mungbean. Mungbean produced 6.0% more seed yield in the year 2007 than 2008. The yield variation was possibly due to variation in climatic conditions where as 30% more precipitation during the first growing season. The increasing trend of seed yield was noted in PK+ inoculation that was 33% higher as compared to control plots. The yield increment was attributed to nitrogen fixation by Rhizobium and full utilization of P and K during growing period because when phosphatic fertilizer were applied in combination with Rhizobium it enhanced the growth and yield of legumes. Though in half PM + half PK + inoculation seed was inoculated with Rhizobium but due to mineralization of poultry manure, N was readily available to Rhizobia resulted into poor nodulation. Secondly, enhanced 1000-seed weight and number of seeds pod^{-1} in PK + inoculation with Rhizobium contributed to final yield. Results are in line with the findings of Fatima et al. (2007) who reported that phosphorus is important for plant growth and its deficiency limits legume production in most of agriculture soils. Similarly, phosphorus along with Rhizobium inoculation increased growth, yield and nitrogenase activity as well as improved soil fertility for sustainable agriculture (Fatima et al., 2007). Intercropping reduced the mungbean yield by 28% compared to sole cropping of mungbean. Reduction in yield might be due to interspecific competition for below and above ground growth factors i.e., soil moisture, nutrient, space and solar radiation. Tsubo et al. (2005) bean yields were decreased in the maize-bean intercropping systems. Adu-Gyamfi et al. (2007) reported that legumes in intercropping did not compete with maize for nitrogen.

The biological yield refers to the total dry matter accumulation of a plant system. Biological yield of mungbean was significantly affected due to addition of chemical fertilizers, organic manures and biofertilizers either alone or in combination (Table 2). Intercropping and growing season significantly affected biological yield of mungbean. The interactive effect was statistically non-significant between intercropping systems and added fertility treatments. Maximum biological yield of mungbean (3918 kg ha^{-1}) was recorded in PK + inoculation followed by half PM

Table 2: *Effect of different fertility treatments and intercropping system on grain yield, biological yield, 1000 - grain weight and harvest index (%) of mungbean*

Cropping Systems	Grain Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	1000 - Grain Weight (g)	Harvest Index (%)
Sole mungbean	1303 a	3864 a	41.40	33.65 a
Maize + mungbean	929 b	3037 b	39.85	30.52 b
Fertility Protocols				
Control	870 d	2930 d	38.61 d	29.54 b
PK + inoculation	1292 a	3918 a	42.83 a	32.76 a
NPK	1130 c	3464 c	40.65 bc	32.47 a
Poultry manure (PM)	1087 c	3319 c	39.60 cd	32.59 a
Half PM + half PK+ inoculation	1200 b	3620 b	41.43 b	33.05 a
LSD	45.37	146.00	1.10	1.70
Years				
Year 2007	1152 a	3546 a	41.10	32.14
Year 2008	1079 b	3354 b	40.15	32.03

** Means not sharing a common letter in a column or a row are significantly different at 0.05 probability;* **N**: *Nitrogen;* **P**: *Phosphorus;* **K**: *Potassium; Inoculation with Rhizobium*

+ half PK + inoculation with the yield of (3620 kg ha^{-1}). NPK and poultry manure showed statistically equal yields, respectively. The yield declining trend was noted in absolute control with biological yield of 2930 kg ha^{-1} compared to other treatments. Results were in conformation to findings of Hayat et al. (2008). Mungbean gave 5% more biological yield in 2007 than 2008 due to more rainfall prevailed during growing season as shown in Figure 1 and 2. In cropping systems, maximum biological yield (3864 kg ha^{-1}) was recorded in sole mungbean. Biological yield of mungbean was reduced by 21% in intercropping as compared to sole mungbean. Intercropping systems between cereals and legumes may face a complex series of inter and intra-specific interaction geared by modifications and utilization of light, water, nutrients and enzymes (Evans et al., 2001).

Weight of 1000-grain mungbean varied significantly in response to different fertility amendments. Years and interactions between cropping systems and fertility treatments showed non-significant variations (Table 2). Highest 1000-grain weight of mungbean (42.83 g) was recorded in plots treated with PK + inoculation followed by half PM+ half PK+ inoculation with 1000-grain weight of 42.21 g. Sole poultry manure gave statistically equal 1000-grain weight to that of NPK. Lowest 1000-grain weight (38.78 g) was noted in control treatments. The mungbean gave 2% more 1000-grain weight in the year 2007 than 2008. The improvement in 1000-grain weight in 2007 is attributed to favourable growing season which enhanced nutrient and water uptake. Secondly, phosphorus is important constituent for grain legume and the highest 1000-grain weight obtained was due to balanced supply of nutrients.

Improved harvest index represents increased physiological capacity to mobilize photosynthates and translocate them into organs having economic yield. Both of the intercropping and fertility treatments significantly affected the Harvest Index (HI) of mungbean.

Similarly, year effect was significant but the interactions between cropping systems and fertility treatments were non-significant (Table 2). Higher HI of mungbean (33.05%) was recorded treated with half PM+ half PK+ inoculation with no distinction compared to rest of the treatments viz. PK + inoculation (32.76 %), NPK treatments (32.47%) and HI (32.59%) in poultry manure. Minimum HI of mungbean (29.54 %) was noted in control plots. The mungbean gave more harvest index in 2007 compared to 2008 was attributed climatic variations. In cropping systems, higher HI (33.65%) was observed in sole mungbean. Mungbean intercropped in maize gave registered HI (30.52%). The lower HI% in intercropping was attributed to interspecific both below and above ground competition between cereal and legume.

Higher maize yield was noted in sole maize as compared to intercropping of maize + mungbean. Maximum grain yield of maize (4830 kg ha^{-1}) was recorded in half PM + half PK + inoculation with PGPR followed by NPK with an average yield of 4167 kg ha^{-1}. Maize grain yield in poultry manure was statistically at par with that of NPK (Table 3). Kumar et al. (2008) reported that growth parameters, yield attributes, grain yield, maize grain equivalent yield and total N uptake by maize increased significantly with increasing N rate in combination with PGPR + organic manure. The results also were also in consistent with the findings of Ibeauchi, et al. (2007) who elucidated that combined application of NPK and PM gave significantly higher maize grain yield, dry matter and leaf area.

Table 3: *Two year mean of grain yield of maize influenced by different fertility treatments and intercropping system*

Cropping Systems	Grain Yield (kg ha^{-1})
Sole maize	4002
Maize + mungbean	3965
Fertility Protocols	
Control	2984 d
PK + inoculation	3897 c
NPK	4167 b
Poultry manure (PM)	4058 bc
Half PM + half PK+ inoculation	4831 a
LSD	180.00

Means not sharing a common letter in a column or a row are significantly different at 0.05 probability; **N**: *Nitrogen;* **P**: *Phosphorus;* **K**: *Potassium; Seed inoculation with plant growth promoting rhizobacteria (PGPR)*

Table 4: *Effect of different fertility treatments and intercropping systems on land equivalent ratios of maize + mungbean intercropping system*

Treatments	Land Equivalent Ratio (LER)		
	LER Partial (Maize)	LER Partial (Legume)	Total LER
Control	0.99	0.71	1.70
PK + inoculation	0.96	0.82	1.78
NPK	0.96	0.77	1.73
Poultry manure (PM)	0.98	0.76	1.74
Half PM + half PK+ inoculation	0.96	0.80	1.76

N: *Nitrogen;* **P**: *Phosphorus;* **K**: *Potassium; Maize seed inoculation with plant growth promoting rhizobacteria (PGPR) and mungbean seed inoculation with Rhizobium*

Land equivalent ratio (LER) reflects the extra advantage of intercropping system over sole cropping system (Table 4). Total LER values were more than unity indicated an advantage of intercropping over sole system in terms of the use of environmental resources for plant growth. In present study, partial LER of intercropped maize was more than sole crops with maximum (0.96) LER when intercropped with mungbean. Maximum (0.70) partial LER of mungbean was observed in intercropping systems. Total (1.66) LER in maize + mungbean intercropping systems indicated that 66% more area would be required from respective sole cropping system to recover the yield of intercropping system. Kamanga, et al. (2010) reported that cereal-legume intercropping is more productive and profitable cropping system in comparison with solitary cropping.

Soil reaction is the most important single chemical characteristics influencing many physical and chemical properties of soil. In Table 5, it was noted that sole cropping and intercropping under PM displayed increase in values of soil pH from 1-2%. This might be due to higher calcium content of PM. Residual soil nitrogen was depleted in plots under sole maize in control plots (-9.35). There was increase in residual NO_3 Nitrogen when sole legumes were grown or in association with maize. This increase was due to symbiotic N fixation by legumes. Phosphorus was depleted in intercropping systems compared to sole cropping systems. However, maximum decline of P (-14.81) were recorded in maize + mungbean intercropping with control treatment and minimum depletion (-5.93) was recorded in sole mungbean treated with PK + inoculation. Rose et al. (2010) reported that higher capacity for availability of various P fractions to legume and non-legume crops varied in soils with contrasting P dynamics. Fertilizer application, intercropping of legumes with maize and combination of intercropping and fertilization showed that sole maize in control plots treatment depleted more potassium (-21.53). Effect on organic matter was noted to be increasing one due to growing of legumes, intercropping of legumes with maize and application of fertilizer also influenced organic matter of soil. Wenhui et al. (2010) reported that the application of organic manure (OM) and OM + NPK increased soil fertility, soil carbon and modified soil reaction.

Conclusions

Higher values for yield contributing factors and grain

Table 5: *Post harvest analysis (2008)*

Cropping Systems	Fertility Treatment	pH	NO_3-N (ppm)	P (ppm)	K (ppm)	(O.M %)
Sole maize	Control	8.25 (0.0)	3.49 (-9.35)	5.85 (-13.33)	58.31 (-21.53)	0.58 (-7.94)
	PK + inoculation	8.25 (0.0)	3.62 (-5.97)	6.27 (-7.11)	62.24 (-16.24)	0.61 (-3.17)
	NPK	8.25 (0.0)	3.61 (-6.23)	6.23 (-7.70)	62.24 (-16.24)	0.61 (-3.17)
	Poultry manure (PM)	8.26 (+0.1)	3.52 (-8.57)	7.21 (+6.81)	67.58 (-9.06)	0.66 (+4.76)
	Half PM + half PK+ inoculation	8.25 (0.0)	3.53 (-8.31)	7.15 (+5.92)	66.15(-10.98)	0.66 (+3.17)
Sole mungbean	Control	8.25 (0.0)	4.17 (+8.31)	5.91 (-12.44)	69.61 (-6.32)	0.6 (+1.59)
	PK + inoculation	8.25 (0.0)	4.29 (+11.42)	6.35 (-5.93)	70.75 (-4.79)	0.65 (+3.17)
	NPK	8.25 (0.0)	4.21 (+9.35)	6.31 (-6.52)	70.64 (-4.94)	0.65 (+3.17)
	Poultry manure (PM)	8.27 (+0.2)	4.20 (+9.09)	7.42 (+9.92)	78.31 (+5.38)	0.69 (+9.52)
	Half PM + half PK+ inoculation	8.26 (+0.1)	4.24 (+10.12)	7.35 (+8.88)	76.69 (+3.20)	0.66 (+4.76)
Maize + mungbean	Control	8.25 (0.0)	4.12 (+7.01)	6.84 (-14.81)	64.69 (-12.95)	0.64 (+1.59)
	PK + inoculation	8.25 (0.0)	4.23 (+9.87)	5.93 (-12.15)	69.94 (-5.88)	0.67 (+6.35)
	NPK	8.25 (0.0)	4.19 (+8.83)	6.01 (-10.96)	67.54 (-9.11)	0.66 (+4.76)
	Poultry manure (PM)	8.26 (+0.1)	4.16 (+8.05)	7.30 (+8.14)	72.61 (-2.59)	0.70 (+11.11)
	Half PM + half PK+ inoculation	8.25 (0.0)	4.20 (+9.09)	7.18 (+6.37)	71.56 (-3.70)	0.67 (+6.35)
Original values	---	8.25	3.85	6.75	74.31	**0.63**

N: *Nitrogen;* **P**: *Phosphorus;* **K**: *Potassium; Maize seed inoculation with plant growth promoting rhizobacteria (PGPR) and mungbean seed inoculation with Rhizobium and* **O.M**: *organic matter*

yield of mungbean were recorded in PK+ inoculation. Total LER in maize + mungbean intercropping system was higher from respective sole cropping system. Maize/mungbean intercropping was proved to be more productive and efficient system in utilizing land compared to sole cropping. Information reported in this study may be valuable and helpful to agricultural scientists and extension officers with regard to on-farm advice for traditional cropping systems.

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