https://doi.org/10.56946/ jspae.v2i2.196

ISSN: 2957-9082
Journal of Soil, Plant and Environment

ORIGINAL RESEARCH

Pigeon Pea Green Manuring and Nitrogen Fertilization Increase Agronomic Efficiency by Improving Yield and Ear Characteristics of Maize

Haq Nawaz[1,2], Habib Akbar[2], Ahmad Khan[2], Muhammad Arif[2], Muhammad Riaz[3], Shahenshah[2], Muhammad Zuhair[2], Bismillah Khan[2]

[1]Department of Field Crops, Faculty of Agriculture, Isparta University of Applied Sciences, Turkey.
[2]Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar Pakistan.
[3]Biochar Research Unit, Environmental Biogeochemistry Lab, Department of Environmental Sciences and Engineering, Government College University Faisalabad, Allama Iqbal Road, 38000, Pakistan
Corresponding author:
haqnawaz63@aup.edu.pk
haqn7345@gmail.com
Received: 26 July 2023
Revised: 22 August 2023
Accepted: 05 September 2023

ABSTRACT: Green legume incorporation is an encouraging, at least unfinished, substitute for chemical fertilizers, particularly for nitrogen (N). The experiment was conducted in an RCB design with a split plot arrangement replicated four times. Pigeon pea green manuring (GM) of 3.4, 6.3 and 7.3 t ha^{-1} at pre flowering (GM1), at flowering (GM2) and post flowering (GM3) were assigned to the main plots, respectively, and nitrogen levels (N) (0, 70, 100 and 130 kg N ha^{-1}) were allotted to the subplots. Results showed that GM2 significantly improved plant height (183 cm) and leaf area (393.6 cm^2). Whereas, GM1 significantly enhanced biological yield (9826 kg ha^{-1}), grain yield (3500 kg ha^{-1}), thousand grain weight (203.6 g), grain ear^{-1}(319), ear length (18 cm) and ear diameter (11.4 cm) as compared to GM2. Similarly, nitrogen application at the rate of 130 kg ha^{-1} resulted in taller plants, higher leaf area, thousand grain weight, biological and grain yields, harvest index, grains ear^{-1}, ear height, length, weight and diameter than other N levels. The agronomic efficiency (AE) was significantly increased by 13.8 kg kg^{-1} and 11.8 kg kg^{-1} at GM1 and 70 kg N ha^{-1}, respectively. It was concluded from the outcomes of the study that pigeon pea GM at pre flowering stage and 130 kg N ha^{-1} improved maize crop production.

KEYWORDS: Maize, green manures, agronomic efficiency, ear characteristics, yield

1. Introduction

Maize (*Zea mays* L.) is a monoecious plant belongs to family Poacea. It is extensively grown in tropical, sub-tropical and temperate areas of the world. Among cereals crops in Pakistan, it stands third after wheat and rice. Maize is an important source of staple food for humans, feed for cattle and raw material for industry (Arif et al., 2010). It has nutritive value and contains 10% protein, 72% starch, 4.9% oil, 8.6% fibre, 1.8% ash and 3% sugar (Ali et al., 2015). In Pakistan, during the year 2018, maize crop was raised in the area of 1.22 million ha with 5701 thousand tons productivity and 3620 kg ha^{-1} average yield. In most of farming systems, it is used as a fodder crop and also a staple food in different rural areas of the country, especially at high elevations. The maize yield is still very low in Pakistan as compared to other advanced countries. The reasons for low production include poor soil preparation, weed infestation, improper fertilization and low soil organic matter.

Green manure (GM) is the practice of incorporating green and immature crops especially leguminous into the soil for the purpose of improving and fertilizing the soil as it makes available both biologically fixed and mineralized N to the soil (Adesoji et al., 2013). Incorporation of legumes as GM has been used to increase the fertility of soil by adding nutrients and building soil organic matter (Fabumni et al., 2012a). Both legumes and non-legumes have been used successfully to improve the growth and yields of tropical species, especially maize crops. In addition, the allocation of green manures also enhances the benefits of added fertilizers in terms of increased uptake due to the ability of the organic matter to retain nutrients in the rhizosphere (Sakala et al., 2003). Thus, green manures could help tropical smallholders to maintain soil fertility and use added nutrients, especially mobile elements such as N, more efficiently for successful crop production.

Green manures are either applied after being grown in situ during fallow periods, after harvest, or from external sources, when it is referred to as ex situ manuring (Aulakh and Grant, 2008). Incorporating legumes crops contribute greatly in building up of soil fertility and their ability to exploit the enduring water and nutrients in the subsoil that crops cannot utilize, withstand drought, and therefore produce higher yield. Moreover, it is a management practice that is environment friendly and capable of maintaining or building up soil fertility for sustainable maize production (Adesoji et al., 2013). Likewise, other benefits of legumes include opportunity to grow crops at the same time without degrading land and improved soil series and higher water infiltration rate because of their root movement (Rao and Mathuva, 2000). Practicing green manuring in agriculture is also the way of coping and overcoming the effect of change in climate which is presently a global and local concern. Thus, green manuring can reduce the dependence on chemical fertilizers as well as help to extend the period of soil cover (Fabunmi et al., 2012a).

Nitrogen is the most vital component that contributes greatly to the yield of crops and is the most restrictive element in crop productivity (Jin et al., 2012). N is the major yield determining factor and an important plant nutrient required for the production of maize (Adediran et al., 1995). When there is N deficiency in the soil, adding N improves the corn crop seed yield (Wienhold et al., 1995). Ideal management of N improves grain yield, farm profit and NUE while it decreases the chances of leaching N beyond the root zone of the crop (Raun and Johnson, 1999). Though the maize crop is very responsive to N fertilization; however, excessive or constant application of these chemical fertilizers decreases production, damages the quality of the soil, and some other issues of the environment, like contamination of soil water and nitrate leaching are evolved (Ali et al., 2015). Maximum efficiency is obtained when N is applied and is available for uptake by the plant as needed. This suggests that plant uptake of fertilizers N is more efficient when applied just prior to maximum plant need (Arif et al., 2010).

Residue incorporation and nitrogen application are being followed by the farmers who are well experienced in traditional agronomic practices but cannot adopt advance methods and techniques because of poor financial conditions, lack of education and technical skills. In the light of the economic and financial status of the farmers, their education and farming experience, legume incorporation and appropriate integrated nitrogen can be good options to reduce the cost of production. Researchers have experimentally tested these technologies individually; however, the collective effects of legume incorporation in combination with nitrogen have not been thoroughly explored. Therefore, the experiment was planned to investigate the effect of pigeon pea incorporation combined with N fertilizer to improve agronomic efficiency and maize production.

2. Materials and methods

2.1 Experimental Site

The field experiment was performed at the Agronomy Research Farm, The University of Agriculture, Peshawar, Pakistan (34° 1′ 2′′ N, 71° 28′ 5′′ E). The climate at the study site is subtropical and semi-arid, having a mean annual rainfall of 360 mm and mean maximum and minimum temperatures of 40 and 25 °C, respectively in summer from May to September. The soil was silty clay loam and alkaline calcareous (pH 8.23) with electrical conductivity (EC) of 0.16 dS m^{-1} (Table 1). Bulk density (BD) and cation exchanged capacity (CEC) of the soil was 1.35 Mg m^{-3} and 30.1 $cmol_c$ kg^{-1}, respectively. The soil had low native soil organic matter (total organic C 12.7 g kg^{-1} and TN 0.61 g kg^{-1}) and plant available nutrients (available N 23.7 mg kg^{-1} and P 3.20 mg kg^{-1}), and had adequate available K contents (85.8 mg kg^{-1}). Mean monthly rainfall and air temperature data were taken from the meteorological office of Peshawar and is presented in Figure 1.

2.2 Experimental design and treatments

The experiment was conducted in RCB design with a split plot arrangement having four replications. Pigeon pea incorporation (Pre flowering (50 DAS) GM1, at flowering (65 DAS) GM2 and post flowering (80 DAS) GM3 was allotted to the main plots while N levels (0, 70, 100 and 130 kg ha^{-1}) were allocated to subplots.

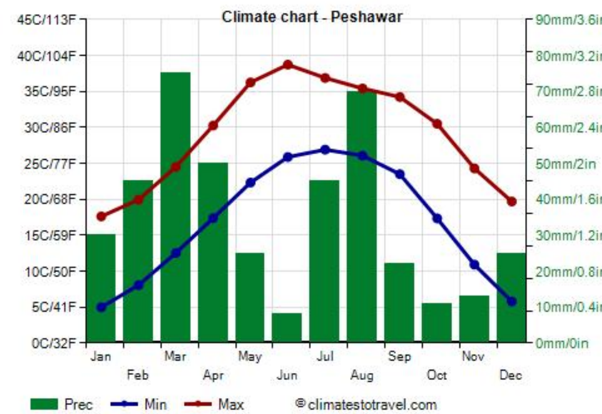

Figure 1. Mean monthly rainfall and air temperature of the experimental period

Pigeon pea crop was sown during the month of April (26th April) and hereafter fresh biomass of (3.4, 6.3 and 7.3 tons ha^{-1}) was incorporated at pre flowering, flowering and post flowering stage of crop, respectively. Azam variety was sown on 14th July after the treatment's application to experimental units. The size of the experimental units was 3 m × 3.5 m (10.5 m^2). Each experimental unit was comprised of five rows, maintained at a distance of 75 cm. A basal dose of 30 (kg ha^{-1}) P at sowing time was supplied from DAP. The amount of nitrogen received through the application of DAP was deducted from urea. Other agronomic practices like weeding, hoeing, thinning and irrigation were performed as required. The crop was harvested on October 20 at proper maturity.

2.3. Measurements

2.3.1. Yield attributes and root dry biomass

To determine leaf area (LA), ten randomly selected leaves were collected from each experimental unit, and their average length and width were measured, with width measurements taken near the stem's base, in the middle of the leaf, and near the tip. The average of these three values was calculated, and the mean leaf area per leaf ($leaf^{-1}$) was determined using the formula: leaf length × leaf width × CF (0.75). For plant height, data were recorded by measuring the height of five random plants in each plot, from the base to the tip, and these measurements were then averaged. Root biomass was quantified by randomly selecting and digging up five plants from the border rows of plots during the grain filling stage. Subsequently, the collected root samples were dried and weighed, and data were obtained from the three central rows at the time of harvesting. Plant numbers were calculated within each plot and then converted to plants per hectare (plants ha^{-1}) using the formula: counted plants per unit area × 10,000 m^{-2}. Thousand grains weight was determined by collecting 1000 grains from the seed lot of each plot and measuring their weight using a digital balance. For recording grain yield, the middle rows of the plots were harvested, and these harvested rows were dried in the sun and threshed separately. Grain yield was measured in the plots and converted into kilograms per hectare (kg ha^{-1}), with data collected from three harvested middle rows of subplots at maturity. Subsequently, the harvested rows were bundled and allowed to dry in the sun, and these bundles were then weighed to calculate the biological yield, which was also converted to kilograms per hectare (kg ha^{-1}). Finally, the harvest index was derived by dividing seed yield by the biological yield.

2.3.2. Ear characteristics

To record ear height, we randomly selected five plants in each plot and, measured the distance from the base to the ear, then calculated the averages. To determine the ear nodal position of maize, we selected five plants in each plot and counted their nodal positions from the base to the ear-bearing node. To assess productive plants, we recorded data by selecting three central rows, each one meter in length, in every plot. We calculated the total number of plants and then counted the eared plants among them. Ear length was measured by selecting five ears from each subplot and determining their length using a ruler; averages were then calculated. Maize ear weight was determined by collecting five ears from each sub-plot, weighing them, and calculating the averages. To calculate grain numbers, we randomly selected five ears from every experimental unit and counted the grains in each ear, averaging the results. Ear diameter was noted by selecting five ears from each experimental unit and measuring their diameter using a measuring scale. The data were averaged, and the total diameter, along with their circumference, was calculated using the expression: Diameter = $2\pi r$."

2.4. Statistical analysis

The recorded data were statistically analyzed using an analysis of variance procedure following a randomized complete block (RCB) design. Means of the data were compared using the least significant differences (LSD) test at a significance level of P ≤ 0.05 when a significant F-test was observed (Steel and Torrie, 1997). Figures were generated by using Prism 8.0 software.

3. Results

3.1. Yield traits

Table 1 exhibited the data of maize plant height as affected by green manuring and N. Both GM and N significantly influenced plant height. The interactive impact of GM × N was found non-significant. A plant height of 183 cm was noted in experimental plots incorporated at the flowering stage followed by plant heights of 175 cm and 173 cm from the plots incorporated at post flowering and pre flowering, respectively. Amongst nitrogen levels, taller plants (192 cm) were recorded from plots supplied with 130 kg N ha^{-1}. Likewise, plants with a height of 178 cm were noted from plots supplied with 100 kg N ha^{-1}. Short stature plants (165 cm) were noted in control plots.

GM and N also significantly influenced leaf area leaf^{-1} (LAL) of maize (Table 1). The interaction of GM × N was not significant. Maximum LAL (393.6 cm^2) was observed from the treatment of green manure incorporated at the flowering stage followed by LAL of 376.7 cm^2 in plots where incorporation at pre flowering stage was done. This was statistically similar to LAL of 375.7 cm^2 in plots green manure was incorporated at post flowering stage. Among nitrogen levels the maximum LAL (412.5 cm^2) was recorded from 130 kg N ha^{-1} followed by LAL (382.9 cm^2) recorded in plots supplied with 100 kg N ha^{-1} in comparison with the lowest LAL (353.2 cm^2) from the control plots.

Data analysis indicated no impact of GM and N rates on plants at maize harvest (Table 1). The GM × N interaction was also not significant. Although the effects of GM and N rates were not significant on plants at harvest however, green manuring at post flowering stage and nitrogen fertilization by 130 kg ha^{-1} showed relatively more plants (67963 ha^{-1}) and (69012 ha^{-1}), respectively. The impact of incorporated legumes (pigeon pea) and nitrogen on grain ear^{-1} of maize was significant. However, the interactive effect of (GM × N) was non-significant (Table 1). Plots incorporated with GM at pre and at flowering stages showed relatively more grains ear^{-1} (319, 311, respectively) followed by 295 grains ear^{-1} from the plots incorporated with green manure at post flowering stage. Plots added with 130 kg ha^{-1} nitrogen produced maximum grains ear^{-1} (336), while the lowest grains ear^{-1} (274) were documented in plots where no N was used (control).

Effects of preceding legume crop incorporation and N rates were significant on 1000 seed weights of maize. However, the GM × N interaction was found to be non-significant (Table 1). Heavier grains (203.6 g) were noted in plots with the incorporation of GM at pre flowering stage. The minimum weight of grains (195.3 g) was noted in plots incorporated with green manure at post flowering stage. Among nitrogen levels, plots applied with 130 kg N ha^{-1} had higher seed weight (214.7 g) which was statistically at par with thousand grains weight (202.6 g) from the plots added with 100 kg ha^{-1} N. Lower thousand seed weight (185 g) was observed in control plots.

Table 1. Response of green manuring and nitrogen fertilizer on root biomass, yield and yield components of maize

Treatments	Plant height (cm)	Plants at harvest (ha^{-1})	Root biomass (g)	Leaf area leaf^{-1} (cm^2)	1000 grain weight (g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{1})	Harvest index (%)
Green manuring (GM)								
GM1	173b	67500	4.5a	376.7b	203.6a	9826a	3500a	35
GM2	183a	66574	4.2b	393.6a	197.3ab	9588b	3258b	35
GM3	175b	67963	4.0c	375.7b	195.3b	9568b	3235b	34
LSD	6.40	ns	0.20	7.50	6.60	219.5	196.14	ns
F-value	7.88	1.32	9.57	21.36	5.22	5.46	6.74	2.55
Nitrogen levels (N kg ha^{-1})								
N1	165c	66419	4.1	353.2c	18.50c	8228d	2669d	33b
N2	174bc	66296	4.3	379.3b	192.7bc	9221c	3201c	35ab
N3	178b	67654	4.2	382.9b	202.6ab	10272b	3588b	35ab
N4	192a	69012	4.3	412.5a	214.7a	10921a	3867a	36a
LSD	10.23	ns	ns	15.48	12.8	522.9	191.94	2.20
F-value	10.65	1.93	0.67	20.75	8.44	61.55	61.57	5.42
Interaction								
GM x N	ns	ns	ns	ns	ns	ns	347.3	ns

Note: Nitrogen levels represents N1=0, N2=70, N3; 100; and N4=130 kg N ha^{-1}, and pigeon pea green manuring represented by GM1 (3.4 t ha^{-1} at 50 days of pre flowering); GM2 (6.3 t ha^{-1} at 65 day of flowering); GM3 (7.3 t ha^{-1} at 80 days of post flowering). Means of the same category followed by different letters are significantly different at 5 % level of probability.

Table 2. Variations in the ear characteristics of maize with the application of green manuring and N fertilization

Treatments	Productive ear plant^{-1}	Grains ear^{-1}	Ear height (cm)	Ear nodary position	Ear length (cm)	Ear weight (g)	Ear diameter (cm)
Green manuring (GM)							
GM1	6.5	319a	77	7	18a	225a	11.4a
GM2	6.4	311a	72	7	17a	212b	12.0a
GM3	6.6	295b	72	7	16b	209b	11.7ab
LSD	ns	14.10	ns	ns	0.90	10.90	0.30
F-value	2.79	9.05	3.42	0.26	7.66	7.74	7.68
Nitrogen levels (kg ha^{-1})							
N1	6.4	274b	64c	6	16c	194c	11.3c
N2	6.3	294b	71b	7	17b	202c	11.5bc
N3	6.5	329b	77ab	7	17b	223b	11.7b
N4	6.7	336a	83a	7	18a	243a	12.2a
LSD	ns	25.7	6.26	ns	0.74	18.55	0.38
F-value	2.65	11.00	13.25	2.69	8.64	11.72	7.64
Interaction							
GM x N	ns	ns	ns	ns	ns	ns	ns

Note: Nitrogen levels represents N1=0, N2=70, N3; 100; and N4=130 kg N ha^{-1}, and pigeon pea green manuring represented by GM1 (3.4 t ha^{-1} at 50 days of pre flowering); GM2 (6.3 t ha^{-1} at 65 day of flowering); GM3 (7.3 t ha^{-1} at 80 days of post flowering). Means of the same category followed by different letters are significantly different at 5 % level of probability

3.2. Crop yield

Data analysis revealed that green manure and N levels significantly affected grain yield of maize. A higher grain yield (3500 kg ha^{-1}) was noted in plots incorporated with GM at pre flowering stage. Similarly, plots incorporated with GM at the flowering stage showed grain yield of 3258 kg ha^{-1} compared with a grain yield of 3235 kg ha^{-1} from the post flowering stage. Among N levels, grain yield of 3867 kg ha^{-1} was noted in plots supplied with 130 kg N ha^{-1} followed by seed yield of 3588 kg ha^{-1} from the plots applied with N at the rate of 100 kg ha^{-1}. Lower grain yield (2669 kg ha^{-1}) was recorded in control plots. The interactive effect (GM × N) was also significant. Figure 2 showed that increment in N from 0 to 130 kg ha^{-1} raised grain yield linearly for green manure incorporation stages. Moreover, once N was raised from 100 to 130 kg ha^{-1} grain yield declined for green manures incorporated at post flowering stage. The highest grain yield (4081 kg ha^{-1}) was observed with 130 kg ha^{-1} N and incorporation at pre flowering stage. Increasing N dose from 100 to 130 with legumes incorporated at flowering and post flowering stage indicated no rise in grain yield. Data analysis indicated that both the treatments (GM and N) had significant impact on maize biological yield (Table 1). More biological yield (9826 kg ha^{-1}) was recorded from green manure incorporated at pre flowering stage. Likewise, experimental units incorporated at flowering stage resulted in biological yield of 9588 kg ha^{-1}. Lower biomass (9568 kg ha^{-1}) was recorded in plots incorporated with green manure at post flowering stage. The interactive effect of GM × N was non-significant. Comparing different N levels, plots supplied with 130 kg ha^{-1} N resulted in more grain yield (10921 kg ha^{-1}) followed by biological yield (10272 kg ha^{-1}) from 100 kg ha^{-1} N. The lowest biological yield of 8228 kg ha^{-1} was observed in control plots. N levels significantly affected the harvest index. Impact of GM and association of GM × N was found non-significant. Plots applied with 130 kg ha^{-1} N resulted in more harvest index (36%). Similarly, experimental units supplied with 100 kg ha^{-1} N revealed harvest index of 35% while minimum harvest index (33 %) was documented in control.

3.3. Ear characteristics of maize

Maize productive ear plants as impacted by GM and N are exhibited in Table 2. Analysis of the data showed a significant effect of N and GM on productive ear plants. Interactive impact of (GM × N) was also found non-significant. Incorporation at post flowering stage and 100 kg ha^{-1} nitrogen indicated relatively more productive plants. Likewise, data analysis showed a significant impact of N on corn ear height but the effect of (GM × N) was non-significant. Plants with ear height of 83 cm were measured in plots with 130 kg ha^{-1} nitrogen. Likewise, 100 kg ha^{-1} N showed ear height of 77 cm. The minimum ear height (64 cm) were reported in control plots.

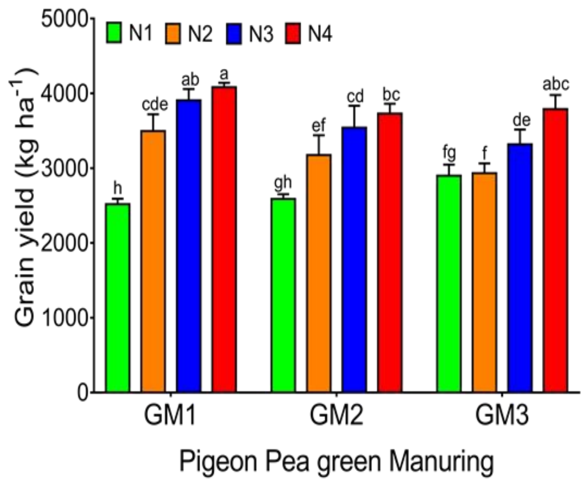

Figure 2. Variation in grain yield with respect to green manuring at different crop stages with nitrogen fertilization.

Data analysis showed no significant effects of green manuring and N on ear nodary position of maize (Table 2). The interactive effect of GM × N was also non-significant. Significant effects of both N and green manuring were found on ear length of maize (Table 2). Interactive effect of GM × N was found non-significant. Experimental units incorporated with green manure at pre flowering stage indicated higher ear length (18 cm). Similarly, ear length of 17 cm was recorded at flowering stage. The lowest ear length (16 cm) was recorded at post flowering stage. Comparing different levels of nitrogen,

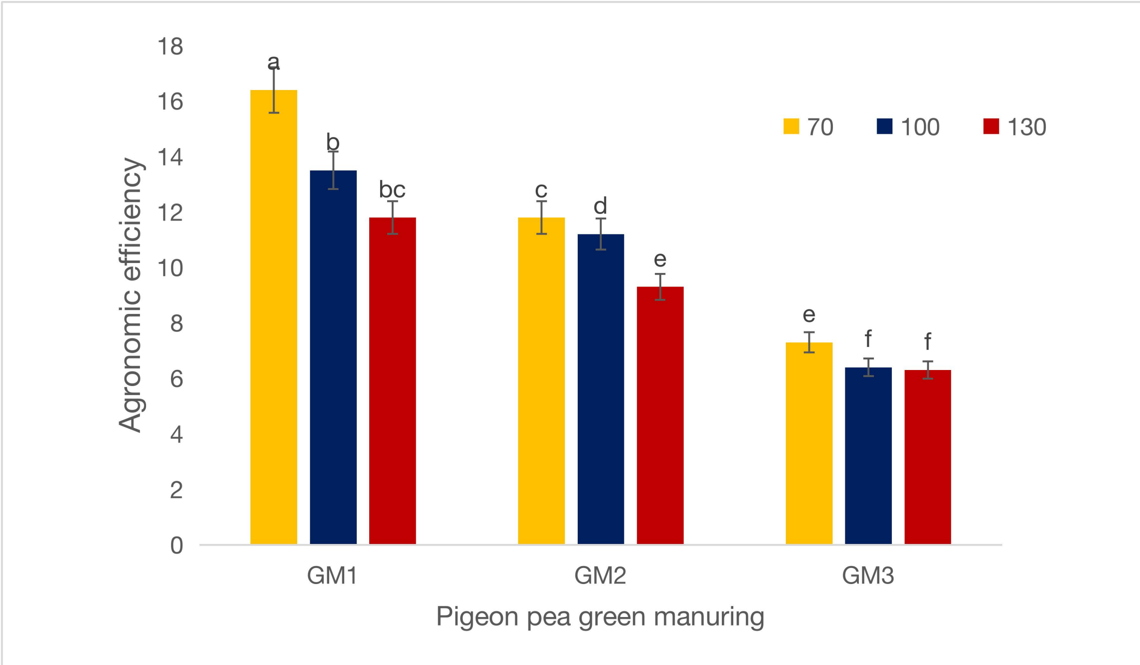

Figure 3. Variation in Agronomic efficiency with respect to green manuring at different crop stages with nitrogen fertilization.

Note: Nitrogen levels represents N1=0, N2=70, N3; 100; and N4=130 kg N ha^{-1}, and pigeon pea green manuring represented by GM1 (3.4 t ha^{-1} at 50 days of pre flowering); GM2 (6.3 t ha^{-1} at 65 day of flowering); GM3 (7.3 t ha^{-1} at 80 days of post flowering). Means of the same category followed by different letters are significantly different at 5 % level of probability.

maximum ear length (18 cm) was noted in plots with the application of 130 kg N ha^{-1}. Likewise, ear length of 17 cm was noted in plots with 70 and 100 kg N ha^{-1}. The lowest ear length of 16 cm was recorded in control.

Analysis showed that GM and N significantly affected the ear weight of maize (Table 2). Maximum ear weight (225 g) was noted with green manure at pre flowering stage followed by 212 g in plots with GM at flowering stage though it was not statistically different from ear weight of 209 g in plots incorporated with GM at post flowering stage. Among nitrogen levels, application of 130 kg ha^{-1} N indicated ear weight of 243 g followed by 223 g ear weight from 100 kg N ha^{-1}. Lower ear weight (194 g) was noted in control. Data analysis indicated that both GM and N had significantly influenced ear diameter (Table 2). Maximum ear diameter (12 cm) was recorded in plots with GM at flowering stage followed by ear diameter (11.7 cm) in plots with GM at post flowering stage while least ear girth (11.4 cm) was measured in plots with GM at pre flowering stage. Comparing levels of nitrogen, maximum ear diameter (12.2 cm) was measured in plots with application of 130 kg N ha^{-1}. Likewise, plots with 100 kg N ha^{-1} had ear diameter of 11.7 cm. The lowest ear diameter (11.3 cm) was recorded in control.

Table 3. Agronomic efficiency (kg kg^{-1}) as affected by green manuring and N fertilizer levels.

Treatments	Agronomic efficiency (kg kg^{-1})
Green manuring	
GM1	13.8
GM2	10.8
GM2	6.6
LSD	2.4
Nitrogen Levels	
N1	0
N2	11.8
N3	10.3
N4	9.1
LSD	1.9
Interaction	
GM*N	3.3

3.4 Agronomic efficiency

Green manuring and N levels significantly affected agronomic efficiency (Table 3). Plots with GM at pre flowering stage had higher agronomic efficiency (AE) of 13.8 kg kg^{-1} followed by green manuring at flowering stage (10.8 kg kg^{-1}). Green manuring at post flowering stage resulted in the lowest AE (6.6 kg kg^{-1}). Among N levels, the N application at the rates of 70 and 100 kg ha^{-1} had higher and statistically similar AE (11.8 and 10.3 kg kg^{-1}, respectively) as compared to 130 kg N ha^{-1} (9.1 kg kg^{-1}).

4. Discussion

Green manure had significantly affected the root biomass (g $plant^{-1}$) of maize. The impact of N and interactive effect of (GM× N) was found non-significant. Green manure at pre flowering stage resulted in more root biomass followed by root biomass of plots incorporated at flowering stage. The lowest root biomass was recorded at post flowering stage. The increase in root biomass with green manuring may be due to application of legumes, has improved soil properties which tend to produce more biomass as a result of porous soil. These finding are in line with Sangakkara et al. (2004) who specified development in growth and root weight with green manure. The Pigeon pea green manured at flowering stage showed maximum leaf area compared with incorporation at pre and post flowering stage. Likewise, plots fertilized with nitrogen produced maximum leaf area. Interaction of (GM × N) for leaf area was found non-significant. Increase in leaf area with incorporated legumes and fertilization of N could be due to the accessibility of N in soil. The documented outcomes are in similarity with Ali et al. (2015). Likewise, Onasanya et al. (2009b) stated, plots treated with N indicated greater plant LA and also leaf area $plant^{-1}$ in comparison of plots in which no N was supplied. These conclusions are also in line with Cox et al. (1993). Maximum height was measured by 130 kg ha^{-1} N, which could be because of more vegetative crop growth and development triggered by N. These outcomes are in accord with those of Fabunmi et al. (2012b) who noted improvement in height of plant with green manuring. Akmal et al. (2010) also reported increased in height of plant with N. The effect of legume green manure and N was significant for yield components (grain ear^{-1} and 1000 seed weight) of maize crop. Green manure at pre flowering stage showed more grains ear^{-1} and thousand grain weight followed with green manure at flowering stage. Lowest grains ear^{-1} and 1000 seed weight was noted at post flowering stage. The obtained outcomes are in similarity with those of Fabunmi et al. (2012b). Likewise, Zakikhani et al. (2016) reported increased in grains number and seed weight with green manure incorporation. Among N levels, application of 130 kg ha^{-1} N indicated more grains number and higher seed weight. The increased in grains numbers and grain weight could be due to the possibility that, N improve yield and yield traits. Nitrogen also increases the availability of nutrients as a result more grains ear^{-1}. The obtained outcomes are in similarity with Amanullah et al. (2009) who specified enhancement in grain ear^{-1} with increment in N. Arif et al. (2010) stated that, nitrogenous fertilizers to maize improved yield traits and yield. The higher seed yield, more grain numbers and more biomass accumulation is because of more exploitation of solar energy, greater production of assimilate and its conversion to starches as a result more grain numbers its weight and greater biomass and grain yield Derby et al. (2004). Nitrogen rates can enhance yield and attributes of yield as reported by El-sheikh et al. (1998). Documented outcomes are in promise with those of Mahmood et al. (2001).

Growing legumes as green manures and nitrogen application had significantly higher grain yield. Interaction of (GM × N) was also found significant. Green manuring at pre flowering stage showed higher grain yield followed by flowering stage. The significant response of grain yield on green manured plots could be ascribed to the nutrients released from the incorporated biomass of legume. The obtained outcomes are in similarity with those of Fabunmi et al. (2012b) and Rao et al. (1983) who documented greater maize seed yield with green manure. N dose of 130 kg ha^{-1} indicated greater seed yield followed with 100 kg N ha^{-1}. The obtained outcomes are in line with Azeem et al. (2014) who obtained more seed yield with 200 kg N ha^{-1}. Productivity of more assimilates depend on more exploitation of solar radiations and its transformation to starches occasioned more seed weight and number that resulted in higher seed yield and biomass Derby et al. (2004). N can increase yield traits and maize yield El-shekh et al. (1998). Significant impact of incorporated green legumes and nitrogen was reported for maize biological yield. Highest maize biological yield was noted from green manure at pre flowering stage followed by flowering stage. The favorable growth and rise in biological yield by legume green manured plots could be due to the increase in the quantity of N fixed by legumes and total of N derived from the incorporated green manure by decomposition. Significant maize growth as a result of green manure was observed by Tanimu et al. (1999). Likewise, William et al. (1992) described increased biomass yield when legumes were incorporated into the soil. Interaction of (GM × N) was noted non-significant. Application of 130 kg N ha^{-1} indicated higher biomass yield followed by 100 kg ha^{-1} N. The more biological yield is possibly because of greater crop vegetative. Imran et al. (2015) documented highest biological yield by 150 kg N ha^{-1}. The obtained outcomes are also in line with those of Akmal et al. (2010). Harvest index which is the competence and capability of crop for transforming the whole dry matters into economic yield was significantly affected by N. Experimental fertilized with 130 kg ha^{-1} nitrogen indicated higher harvest index followed by 100 kg N ha^{-1}. Lowermost harvest index was calculated in the control plot. The differences in harvest index with N due to the vital role of N in plant vegetative growth. Mahmood et al. (2001) obtained maximum harvest index with 180 kg ha^{-1} N. Likewise, differences in harvest index with N were obtained by Sharifi et al. (2016). Lawrence et al. (2008) specified that, the harvest index in corn increases when N rates increases.

Minimum ear length and ear weight were documented in plots incorporated at post flowering stage. ear length and weight generally declined with decreasing nitrogen rates, higher ear length and ear weight resulted from the plots with 130 kg ha^{-1} N. Likewise, with application of 100 kg N ha^{-1}. Lowest ear length and ear weight were noted in control. These findings are in line to Fabunmi et al. (2012). Bakht et al. (2007) who described that ear length improved with increasing N rates. These outcomes are also in promise with Imran et al. (2015) who recorded rise in ear weight with N. further, more ear diameter was observed with green manure at flowering stage followed with post flowering stage. Lowest ear diameter circumference was recorded with incorporation at pre flowering stage. The obtained findings are in accordance with those of Fabunmi and Balogun, (2015) who documented significant influence of green manuring on ear diameter of maize crop. Comparing different levels of nitrogen, maximum ear diameter was noted with 130 kg ha^{-1} N followed with 100 kg N ha^{-1}. The documented outcomes are in agreement with Ogunlela et al. (1998) and Onasanya et al. (2009a) who specified substantial influence of nitrogen on ear diameter.

Agronomic efficiency (AE) calculated in units of yield increase per unit of nutrient applied. Green manuring at pre flowering stage with 130 kg ha^{-1} resulted in more agronomic efficiency. It might be due to the availability of nutrients from the green manuring which was done early and the nitrogen applied. Vanlauwe et al. (2011) stated that application of organic resources in combination with N fertilizer improving agronomic efficiency. These results are also in accordance with those of Fixen et al. (2015). They reported that efficiency measures are greatly influenced by nutrient rate applied, residues, crop management, and by soil fertility.

5. Conclusion

Preceding legume (Pigeon pea) as a green manure had enhanced yield traits and yield of maize crop. Pigeon pea green manure incorporated at pre flowering stage enhanced root biomass, grain number ear^{-1}, thousand seeds weight, grain and biological yield. The application of 130 kg N ha^{-1} showed highest grains numbers, thousand seeds weight, seed yield, biological yield and maize harvest index. Further, Pigeon pea green manuring at pre flowering stage with 130 kg N ha^{-1} showed higher grain yield. Thus ccultivating preceding legume (Pigeon pea) as green manured at pre flowering stage integrated with 130 kg N ha^{-1} fertilization are endorsed for greater grain yield and productivity of maize.

Acknowledgments: We are thankful to The University of Agriculture Peshawar, Pakistan for providing space for experiment.

Conflicts of Interest: The authors declare no conflict of interest.

Availability of Data and Materials: Data will be available on formal request from the corresponding authors.

Authors Contributions: HN, HA and AK planned and conducted the experiment. HA & AK analyzed the data MA, MR & SS helped in research article writing. MZ and BK helped in methodology writing. HN interpret the results and wrote the manuscript.

Funding: Not Applicable (N/A)

REFERENCES

Adediran, J.A., & Banjoko, V.A. Response of maize to nitrogen, phosphorus and potassium fertilizers in the savanna zone of Nigeria. Communication in Soil Science and Plant Analysis. (1995). 26(4): 593-606.

Adesoji, A.G., Abubakar, I.U., Tanimu, B., & Labe, D.A. Influence of incorporated short duration legume fallow and nitrogen on maize (*Zea mays* L.) growth and development in northern guinea savanna of Nigeria. American-Eurasian Journal of Agricultural & Environmental Sciences. (2013). 13(1), 58-67.

Akmal, M., Hameed-ur-Rhman, Farhat, U., Asim, M., & Akbar, H. Response of maize varieties to nitrogen application for leaf area profile, crop growth, yield and yield components. Pakistan Journal of Botony. (2010). 42(3): 1941-1947.

Ali, W., Jan, A., Hassan, A., Abbas, A., Hussain, A., Ali, M., Zuhair, SA., & Hussain, A. Residual effect of preceding legumes and nitrogen levels on subsequent maize. International Journal of Agronomy and Agricculture Research. (2015). 7(1): 78-85.

Amanullah, R. A., Khattak, S.K., & Khattak, R.A. Effects of plant density and N on phenology and yield of maize. Journal of Plant Nutrition. (2009). 32(3): 245-259.

Arif, M., Amin, I., Jan, M.T., Munir, I., Nawab, K., Khan, NU., & Marwat, K.B. Effect of plant population and nitrogen levels and methods of application on ear characters and yield of maize. Pakistan Journal of Botony. (2010). 42(3): 1959-1967.

Aulakh, M.S., & Grant, C.A. Integrated nutrient management for sustainable crop production. Hawthorn Press, New York. (2008). p.422.

Azeem K., Khalil, S.K., Khan, F., Shah, S., Qahar, A., Sharif, M., & Zamin, M. Phenology, yield and yield components of maize as affected by humic acid and nitrogen. Journal of Agriculture. Sciences. (2014).6(7): 286-293.

Bakht, J., Siddique, M.F., Shafi, M., Akbar, H., Tariq, M., Khan, N., Zubair, M., & Yousef, M. Effect of planting methods and nitrogen levels on the yield and yield components of maize. Sarhad Journal of Agriculture. (2007). 23(3): 544-559.

Cox, W.J., Kalonoge, S., Cherney, D.J., & Raid, W.S. Growth yield and quality of forage maize under different nitrogen management practices. Agronomy Journal. (1993). 85: 341-347.

Derby, N.E., Casey, F.X/M., Knighton, R.E., & Steel, D.D. Midseason nitrogen fertility management for corn based on weather and yield prediction. Agronomy Journal. (2004). 96: 494-501.

El-Sheikh, F.T. Effect of soil application of nitrogen and foliar application with manganese on grain yield and quality of maize (*Zea mays* L). Proc. 8th Conf. Agron., Suez Canal Univ. Ismailia, Egypt. (1998) pp. 182-189.

Fabunmi, T.O., & Balogun, R.O. Response of maize to green manure from varying populations of cowpea in a derived savannah of Nigeria. African Journal of food and Agriculture. (2015). 15(3): 10138-10152.

Fabunmi, T.O., Adigbo, S.O., Odedina, J.N., & Olasunkanmi, T.O. Effects of planting dates on green manure of cowpea, response of succeeding maize in a derived savanna ecological zone of Nigerian Journal of Agriculture Sciences. (2012b). 4(7): 9752-9760.

Fabunmi, T.O., Agbonlahor, M.U., Odedina, J.N., & Adigbo, S.O. Profitability of pre-season green manure practices using maize as a test crop in a derived Savanna of Niegeria. Pakistan Journal of Agriculture Sciences. (2012a). 49(4): 593-596.

Fixen, P., Brentrup, F., Bruulsema, T., Garcia, F., Norton, R., & Zingore, S. Nutrient/fertilizer use efficiency: measurement, current situation and trends. Managing water and fertilizer for sustainable agricultural intensification. (2015). 270, 1-30.

FRG. Fertilizer Recommendation Guide, BARC, Dhaka. (2012). 50-51p.

Imran, S., Arif, M., Khan, A., Khan, M.A., & Shah, W. Effect of nitrogen levels and plant population on yield and yield components of maize. Advances in Crop Science Technology. (2015).3(2): 170-189.

IUSS Working Group W.R.B., (2006). World Reference Base for Soil Resources 2006: a Framework for International Classification, Correlation and Communication, 2nd edition. Food and Agriculture Organization of the United Nations, Rome.

Jin, L.C., Li, H., Zhang, B., Dong, J., Liu, S., & Peng, L. Effects of integrated agronomic management practices on yield and nitrogen efficiency of summer maize in North China. Field Crop Research. (2012). 134: 30-35.

Lawrence, J.R., Ketterings, Q.M., & Cherney, J.H. Effect of nitrogen application on yield and quality of corn. Agronomy Journal. (2008). 100(1): 73-83.

Mahmood, M.T., Maqsood, M., Awan, T.H., & Sarwar. R. Effect of different levels of nitrogen and intra row spacing on yiled and yield components of maize. Pakistan Journal of Agriculture Sciences. (2001). 38(2): 48-51.

MNSF&R. (2017-18). Agriculture Statistics of Pakistan. Ministry of National Food Security and Research. (Economic wing) Government of Pakistan. 17-19.

Ogunlela, V.B., Amoruwa G.M., & Ologunde, O. Growth, yield components and micronutrient nutrition of field-grown maize (*Zea mays* L.) as affected by nitrogen fertilization and plant density. Fertilizer Research. (1998). 17:189-196.

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Nwilene, F.E., & Oyelakin, O.O. Effect of different levels of nitrogen and phosphorous fertilizers on the growth and yield of maize in Southwest Nigeria. International Journal of Agriculture Research. (2009a). 4(6): 193-203.

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Oikeh, S., Nwilene, F.E., & Oyelakin, O.O. Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers in Southern Nigeria. World Journal of Agriculture Sciences. (2009b). 5(4): 400-407.

Rao, J.V.D.K., Dart, P.J., & Sastry, P.V.S.S. Residual effect of pigeon pea (*Cajanus Cajan* L.) on yield and nitrogen response of maize. Experimental Agriculture. (1983).19: 131-141.

Rao, M., & Mathuva, M. Legumes for improving maize yields and income in semi arid Kenya. Agriculture ecosystem and environment. (2000). 78(2): 123-137.

Raun, W.R., & Jhonson, G.V. Improving nitrogen use efficiency for cereal production. Journal of agronomy. (1999). 91, 357-363.

Sakala, W.O., Kumwenda, J.D.T., & Saka, A.R. The potential of green manures to increase soil fertility and maize yields in Malawi. Biological Agriculture and Horticulture. (2003). 21: 121-130.

Sangakkara, M., Liedgens, A., Soldati, & Stamp, P. Root and shoot growth of maize (*Zea mays* L.) as affected by incorporation of crotalaria juncea and tithonia diversifolia as green manures. Journal of Agronomy and Crop Sciences. (2004). 190: 339-346.

Sharifi, R.S., & Namvar, A. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). Biologija. (2016). 62(1): 35-45.

Steel, R.G.D., & Torrie, J.H. (1997). Principles and procedures of statistics 2nd ed. McGraw Hill, New York.

Tanimu, J. Effect of forage legumes on soil improvement and the performance of maize in the nothern guinea savanna of Nigeria. Unpublished M.Sc. Thesis Ahmadu Bello University, Zaria, Nigeria. (1999). pp: 115.

Vanlauwe, B., Kihara, J., Chivenge, P., Pypers, P., Coe, R., & Six, J. Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. Plant and soil. (2011). 339(1), 35-50.

Wienhold, B.J., Trooien, T.P., & Reichman, G.A. Yield and nitrogen use efficiency of irrigated corn in the northern Great Plains. Agronomy Journal. (1995). 87: 842-846.

William, E.J. Nitrogen fertilizer and dairy manure effects on corn yield and soil nitrate. Journal of Soil Science Society of America. (1992). 56: 148-154.

Zakikhani, K., Kashani, A., & Paknejad, F. Effect of nitrogen level, green and animal manure on the growth attribute of corn crop. Journal of Experimental Biology and Agriculture Sciences. (2016). 4(2): 225.231.

How to cite this article:

Nawaz, H., Akbar, H., Khan, A., Arif, M., Riaz, M., Shahenshah, Zuhair, M., & Khan, B. Pigeon pea green manuring and nitrogen fertilization increase agronomic efficiency by improving yield and ear characteristics of Maize. Journal of Soil, Plant and Environment (2023); 2(1)-pp; 2-15