Enhancing Maize Performance Through Integrated Nutrient Management

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A study entitled "Enhancing Maize Performance through Integrated Nutrient Management" was conducted at NARC, Islamabad, Pakistan, during 2023-24. The experiment was arranged in an RCB design with factorial arrangement. Two maize hybrids, i-e Pioneer-30k08Y and Pioneer-3025W and ten treatments i-e T0= control, T1= Compost, T2= Farm Yard Manure, T3= Poultry Manure (PM), T4= Biochar, **T5=** Bio Fertilizer, **T6=** NPK, **T7=** Foliar application of Moringa leaf extract, T8= Salicylic Acid, **T9=** IAA (Indole Acetic Acid), **T10=** IBA (Indole Butric Acid) were studied. Data on leaf area (cm^2), Plant height (cm), Chlorophyll a content, chlorophyll b content, relative water content, transpiration rate, stomatal conductance, Photosynthetic rate, Cob length (cm), grains cob^{-1},1000-seed weight (g), biological and grain yield (kg ha^{-1}) were measured. Performance of maize hybrid Pioneer-30k08Y showed promising results regarding growth and yield. Application of farmyard manure also showed maximum results and improved growth and yield of maize hybrids. As this study was only conducted using maize hybrids, it is advisable to experiment with various varieties of maize along with fertilizer combinations to check their synergistic effects for more reliable and acceptable recommendations in the future.

Keywords: Farmyard Manure, NPK, Poultry Manure, Compost

Introduction:

Pakistan's economy is largely dependent on agriculture. However, despite favorable conditions, the sector continues to underperform in terms of yield per hectare. After rice and wheat, maize ranks as the third most important cereal crop worldwide, contributing 62% of global cereal production and often referred to as the 'king of cereals.' It serves as a crucial source of food and feed, while its expanding industrial applications have further strengthened its role in the agricultural economy. Maize is not only used by humans as a food grain, but it also serves as a source of feed for cattle and fowl. Maize is used as an industrial raw material to make corn oil, starch, and corn flakes, among other things [1].

Maize is the third most important grain crop in Pakistan, contributing 2.9% to the country's total agricultural value and 0.6% to its GDP. Maize was grown on thousands of hectares in 2019-20, a rise of 2.9 percent over the previous year's 1,374 thousand hectares. Compared to the previous year's output, maize production increased by 6.0%, reaching 7.2 million tons [2].

The two most significant variables that improve plant yield and productivity are fertilizer application and mineral uptake/accumulation [3][4]. Minerals like nitrogen, phosphorus, and potassium can impact plant development and essential oil production [5]. Nitrogen has a major impact on yield and yield components [6]. Therefore, optimizing nitrogen management in hybrid maize is essential for achieving maximum yield [7].

Seaweed extract is a natural biostimulant with cytokinin- and auxin-like properties, capable of enhancing endogenous cytokinin activity in plants [8]. Humic acid, which increases stress resistance as well as plant growth and nutrient absorption [9]. Moringa has recently gained significant attention as a natural source of plant growth regulators (PGRs) and antioxidants [10]. Salicylic acid (SA) is thought to have a function as a natural thermogenesis indicator in a variety of plants, as well as controlling ion absorption by roots and stomatal conductivity [11]. Several studies have highlighted its role as a key component of plant disease resistance, contributing to the plant's response under adverse environmental conditions [12].

The auxin family's most significant member is probably indole-3-acetic acid (IAA). It is the most abundant, physiologically active, and naturally occurring auxin in plants [13]. IAA is susceptible to UV-B-induced damage via direct photo degradation and/or enhanced activity of IAA oxidase enzyme [14].

The use of organic manures is gaining popularity worldwide as soil fertility continues to decline. In contrast, the regular application of chemical fertilizers poses potential risks to the environment [15]. Combining organic and synthetic nutrition sources, on the other hand, not only supplies essential nutrients but also has a number of beneficial interactions that result in greater efficiency and, as a consequence, decreased environmental hazards [16]. The use of external inputs such as farmyard manure has become essential; however, due to the large quantities required to meet crop nutritional demands, its full benefits have not been realized [17]. The demand for renewable energy sources and lower fertilizer costs has resurrected the usage of organic manure across the world [18]. Increased usage of organic materials is recommended for a variety of reasons, including improved environmental conditions and public health [19]. However, because it is large, the cost of shipping and handling prevents peasant farmers from using it. Farmyard manure slowly releases nutrients and stimulates soil microbial biomass.

Biochar contains several important plant nutrients that influence maize crop development. Maize yield and nutrient absorption were significantly enhanced when biochar was applied at a higher rate in combination with other commercial fertilizers [20]. Biochar encourages soil microbial activity, which leads to increased carbon storage in the soil and lowers the need for synthetic fertilizer. By conserving nitrogen, decreasing nitrous oxide emissions, and improving cation exchange capacity, biochar can assist in controlling nitrogen losses [21]. An experimental study was planned with the following objectives:

Objectives:

To evaluate the impact of the growth regulator on the physiological attributes of maize.

To assess the effect of inorganic and organic amendments on the growth and yield of maize.

Materials and Methods:

The study was conducted at the National Agricultural Research Centre (NARC), Islamabad, Pakistan, during 2023–2024. Studying this topic in Islamabad is important because its unique climate, soil, and ecology influence crop growth, pollinator activity, and pest incidence. Findings will provide location-specific insights to help optimize management practices and improve yield and quality.

Experimental Soil:

Soil samples were randomly collected from a depth of 0–15 cm and subsequently combined to prepare a composite sample. These samples were analyzed for various physicochemical properties using standard protocols.

Table 1. Soil physiochemical analysis of the experimental site

Soil texture	pH value	EC	N (%)	P (ppm)	K (ppm)	Organic matter	Ca+	Mg+	Hco_3	Cl
Silty Clay loam	7.75	1.21	0.072	8.74	76	0.50	5.20	0.70	5.6	0.10

Experimental Design:

A two-factor factorial experiment was established under a Randomized Complete Block Design (RCBD) with three replications. The dimensions of each experimental plot were 2.5 m × 5 m. All agronomic operations were carried out uniformly and evenly in all treatments throughout the study period. The rest of the treatments were maintained as per the experimental protocol.

The treatment detail is as follows:

Factor A: Maize hybrids:

H1 = Pioneer-3025W H2 = Pioneer-30k08Y

Factor B: Organic and inorganic amendments

T0= control	**T1=** Compost
T2= Farmyard Manure	**T3=** Poultry Manure (PM)
T4= Biochar	**T5=** Bio Fertilizer

T6= NPK	**T7** Foliar application of Moringa leaf extract
T8= Salicylic Acid	**T9=** IAA (Indole Acetic Acid)
T10= IBA (Indole Butyric Acid)	

Preparatory Cultivation:

The experimental plots were ploughed twice and prepared to a fine tilth, followed by crosswise harrowing to ensure proper leveling and adequate drainage. The field was divided into subplots as per the layout of the experiment.

Sowing:

Maize hybrids were sown at a spacing of 90 cm apart. Seed rate of 25 kg ha^{-1} was used.

Plant Protection Measures:

To detect visual variations between the treatments and any kind of infestation by weeds, insects, and diseases, the field was visited from time to time so that major pest losses could be reduced.

Harvesting:

All plots were harvested manually, and the plants were left in the field for three weeks to dry. After three weeks, the entire plot's ears were husked and dried in the sun for two days before being threshed.

Observations on the Crop:

Plant Height (cm):

Plant height was measured when the selected plants for data collection from each plot matured.

Leaf Area $Plant^{-1}$:

The leaf area was measured after each leaf was removed using scissors. The ratio of leaf area to ground area was used to create the leaf area index.

Photosynthetic Attributes:

Photosynthetic attributes were determined by using a portable infrared gas analyzer.

Leaf Chlorophyll Content:

Leaf chlorophyll concentration was determined by grinding a 0.5 g leaf sample in 80 percent acetone to extract chlorophyll. At 663 and 645 nm, the absorbance of the filtrate was measured, and the chlorophyll content was estimated with the following formula:

Ch-a=12.25A663 – 279A645

Ch-b=21.5A645 – 5.1A663

Relative Water Content:

Mayak et al.'s (2004) method was used to calculate RWC

$$(RWC)\ \% = \frac{FW - DW}{FTW - DW}$$

Grain Rows $Cobs^{-1}$:

From each plot, five cobs were randomly sampled, and the grain rows per cob were counted.

Grains Cob^{-1}: To determine grains per cob, five cobs were harvested from randomly selected plants in each subplot, and the number of grains was counted to obtain the average.

1000 Grain Weight (g):

Hundred seed weight was measured after taking a hand sample of 1000 grains from each treatment.

Grain Yield (kg ha^{-1})

After threshing and winnowing, the weight of clean seeds from each plot was recorded and subsequently converted into kg ha^{-1}.

Biological Yield (kg ha^{-1}):

The weight of the whole plant, excluding roots, was measured after harvest and converted into kg ha^{-1}.

Harvest Index (%):

Harvest index was calculated by the formula:

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Statistical Analysis:

Analysis of variance was performed to confirm the variability of data and the validity of results using computer-based software Statistix 8.1. The differences amongst treatments were separated using the least significant difference test (LSD) at a 0.05 probability level [22].

Results and Discussion:

Plant height (cm):

Analysis of variance (ANOVA) showed that the application of organic and inorganic amendments had a significant effect on the plant height of maize hybrids. The interaction between maize hybrids and these amendments was also found to be significant. Table 1 shows that the tallest plants (204.8 cm) were observed in the maize hybrid Pioneer-30K08Y, followed by Pioneer-3025W (183.25 cm). Regarding organic and inorganic amendments, taller plants (223.43 cm) were observed with the application of farmyard manure, followed by (218.85 cm) poultry manure application, whereas shorter plants (164.57 cm) were recorded in the control. Regarding the interaction, Figure 1 indicates that the tallest plants (235.87 cm) were recorded in maize hybrid Pioneer-30K08Y with the application of farmyard manure. Statistically similar results (230.4 cm) were obtained for Pioneer-30K08Y with poultry manure application. In contrast, the shortest plants (154.57 cm) were observed in the control treatment of maize hybrid Pioneer-3025W.

Leaf Area plant^{-1} (cm^2):

Leaf area plant^{-1} (cm^2) of maize hybrids was significantly influenced by the application of organic and inorganic amendments. The interaction of maize hybrids and organic and inorganic amendments was also statistically significant. Mean comparison of hybrids revealed that maximum leaf area (1182 cm^2) was observed in maize hybrid Pioneer-30k08Y, whereas minimum (1147 cm^2) was recorded in hybrid Pioneer-3025W. Regarding treatment application, maximum leaf area plant^{-1} (1222.2 cm^2) was observed with the application of farm yard manure, followed by (1215 cm^2) poultry manure application, whereas minimum leaf area plant^{-1} (1100.7 cm^2) was observed in control treatments (Table 1). Regarding the interaction, Figure 2 shows that the maximum leaf area per plant (1232.7 cm^2) was recorded in maize hybrid Pioneer-30K08Y with the application of farmyard manure. Statistically similar results (1228.7 cm^2) were obtained for Pioneer-30K08Y with poultry manure application. Minimum leaf area $plant^{-1}$ (1076 cm^2) was recorded in maize hybrid Pioneer-3025W with the control treatment.

Photosynthetic Rate (µmole $m^{-2}s^{-1}$):

The effect of organic and inorganic amendments on the photosynthetic rate of maize hybrids is presented in Table 1. Analysis of variance (ANOVA) indicated that maize hybrids, amendments, and their interaction had a significant influence on photosynthetic rate. The highest photosynthetic rate (20.38 µmole $m^{-2}s^{-1}$) was recorded with the application of inorganic fertilizer (NPK), followed by (19.61 µmole $m^{-2}s^{-1}$) farmyard manure application, whereas the lowest photosynthetic rate (12.03 µmole $m^{-2}s^{-1}$) was recorded in the control. Concerning hybrids, the highest photosynthetic rate (18.07 µmole $m^{-2}s^{-1}$) was recorded in hybrid Pioneer-30k08Y, whereas the lowest (14.03 µmole $m^{-2}s^{-1}$) was recorded in Pioneer-3025W. Regarding the interaction, the highest photosynthetic rate (21.74 µmol m^{-2} s^{-1}) was observed in maize hybrid Pioneer-30K08Y with the application of inorganic fertilizer. Statistically similar results (21.36 µmol m^{-2} s^{-1}) were obtained with farmyard manure on the same hybrid, whereas the lowest rate (9.8 µmol m^{-2} s^{-1}) was recorded in Pioneer-3025W under control conditions (Figure 3).

Stomatal conductance (mmole m^{-2} s^{-1}):

Table 1 shows that maize hybrids, organic and inorganic amendments, as well as their interaction, significantly influenced stomatal conductance. Maximum stomatal conductance was recorded in maize hybrid Pioneer-30k08Y, whereas minimum was recorded in Pioneer-3025W. With respect to treatment application, the maximum stomatal conductance was recorded under the application of inorganic fertilizer (NPK). Statistically similar results were observed with the application of farmyard manure and poultry manure, whereas minimum stomatal conductance was recorded in the control. Regarding the interaction (Figure 4), the maximum stomatal conductance was recorded in maize hybrid Pioneer-30K08Y with the application of inorganic fertilizer, while the minimum was observed in Pioneer-3025W under control conditions.

Transpiration rate (mmole m^{-2} s^{-1}):

The effect of organic and inorganic amendments on transpiration rate of maize hybrids is presented in Table 1. Similar to photosynthetic rate and stomatal conductance, transpiration rate was also significantly influenced by maize hybrids, organic and inorganic amendments, as well as their interaction. The highest transpiration rate was recorded with the application of inorganic fertilizer (NPK), followed by farmyard manure application, whereas the lowest transpiration rate was recorded in the control. Regarding hybrids, the highest transpiration rate was recorded in hybrid Pioneer-30k08Y, whereas the lowest was recorded in Pioneer-3025W. Concerning the interaction, the highest transpiration rate was recorded with the application of inorganic fertilizer on maize hybrid Pioneer-30k08Y, whereas the lowest transpiration rate was recorded in hybrid Pioneer-3025W under controlled conditions. Compared to the control, exogenous application of amendments enhanced chlorophyll content and gas exchange characteristics (Fig. 5).

Table 1. Effect of organic and inorganic amendments on plant height (cm), Leaf area plant^{-1} (cm^2), Photosynthetic rate (µmole m^{-2}s^{-1}), Stomatal conductance (mmole m^{-2} s^{-1}), and Transpiration rate (mmole m^{-2} s^{-1}) of maize hybrids

Hybrids	**Plant height (cm)**	**Leaf area plant^{-1} (cm^2)**	**Photosynthetic rate (µmole m^{-2}s^{-1})**	**Stomatal conductance (mmole m^{-2} s^{-1})**	**Transpiration rate (mmole m^{-2} s^{-1})**
Pioneer-30K08Y	204.8 a	1182.7 a	18.07 a	211.56 a	6.32 b
Pioneer-3025W	183.2 b	1147.7 b	14.03 b	203.3 b	6.51 a
LSD (0.05)	**1.65**	**6.34**	**0.18**	**1.81**	**0.1**
Treatments					
T0= control	164.5 i	1100.7 f	12.03 i	177.83 h	5.29 g
T1= Compost	186.4 f	1150.7 d	15.56 e	208 d	6.07 e
T2= Farmyard Manure	223.4 a	1222.2 a	19.61 b	231.07 a	7.11 b
T3= Poultry Manure	218.8 b	1215.2 a	18.6 c	232 a	7.16 ab
T4= Biochar	197 e	1188.5 b	16..53 d	219 a	7.08 b
T5= Bio Fertilizer	203.9 d	1180.8 bc	16.36 d	212.63 c	6.78 c
T6= NPK	212.2 c	1190.3 b	20.38 a	234.78 a	7.39 a
T7 Foliar application of Moringa leaf extract	199.4 e	1168.3 c	16.38 d	200.88 e	6.49 d
T8= Salicylic Acid	182.1 g	1138.2 de	14.65 f	188.67 f	5.89 ef
T9 Indole Acetic Acid	174.6 h	1128.5 e	13.61 g	192.55 f	5.8 f
T10= IBA (Indole Butric Acid)	171.6 h	1133.7 e	12.88 h	184.3 g	5.52 g
LSD (0.05)	**3.88**	**14.88**	**0.43**	**4.26**	**0.23**
Interaction (hybrids x treatments)	Figure 1	Figure 2	Figure 3	Figure 4	Figure 5

Relative Water Content (%):

Analysis of variance for relative water content revealed that application of organic and inorganic amendments significantly influenced the relative water content of maize hybrids. The interaction of maize hybrids with organic and inorganic amendments also showed significant results. Table 2 depicted that higher relative water content (73.33%) was in hybrid Pioneer-30k08Y, followed by (80.5%) in maize hybrid Pioneer-3025W. Regarding organic and inorganic amendments, maximum relative water content (83.58%) was observed with the application of farmyard manure, followed by (80.5%) poultry manure application, whereas the lowest relative water content (63.88%) was recorded in the control. As illustrated in Figure 6, maize hybrid Pioneer-30K08Y exhibited the highest relative water content (86.76%) when treated with farmyard manure, closely followed by 82.86% under poultry manure application. Conversely, the lowest relative water content (61.73%) was recorded in Pioneer-3025W under control conditions.

Chlorophyll a (mg g^{-1}):

Table 2 depicts that maize hybrids, organic and inorganic amendments, as well as their interaction, significantly affected chlorophyll a content. Maximum chlorophyll a content (1.46 mg g^{-1}) was recorded in maize hybrid Pioneer-30k08Y, whereas minimum chlorophyll a content (1.17 mg g^{-1}) was recorded in Pioneer-3025W. With respect to treatment application, the maximum chlorophyll a content (1.66 mg g^{-1}) was obtained with the application of inorganic fertilizer (NPK). Followed by statistically similar results with application of moringa leaf extract and farm yard manure, whereas, minimum chlorophyll a content (0.98 mg g^{-1}) was recorded in the control. As shown in Figure 7, maize hybrid Pioneer-30K08Y attained the highest chlorophyll a content (1.84 mg g^{-1}) under inorganic fertilizer application, while the lowest value (0.86 mg g^{-1}) was found in Pioneer-3025W grown under control conditions.

Chlorophyll b content (mg g^{-1}):

Analysis of variance for chlorophyll b content revealed that application of organic and inorganic amendments significantly influenced the chlorophyll b of maize hybrids. The interaction of maize hybrids with organic and inorganic amendments also showed significant results. Table 2 depicts that higher chlorophyll b (0.64 mg g^{-1}) was in hybrid Pioneer-30k08Y, followed by (0.42 mg g^{-1}) in maize hybrid Pioneer-3025W. Regarding organic and inorganic amendments, maximum chlorophyll b (0.74 mg g^{-1}) was observed with the application of inorganic fertilizer, followed by bio fertilizer application, whereas minimum chlorophyll b content (0.29 mg g^{-1}) was observed in the control. Figure 8 depicts the interaction of maize hybrids with the application of various organic and inorganic amendments regarding chlorophyll b content. Statistically similar and at par chlorophyll b content was recorded with application of inorganic fertilizer (NPK) and bio fertilizer to maize hybrid Pioneer-30k08Y, whereas the lowest chlorophyll b content was recorded in Pioneer-3025W in the control treatment.

1000-seed weight (g):

Grain weight is the most important parameter that has a significant contribution to yield. The greater the weight of 1000-grain, the higher the yield is. Analysis of variance for

1000-seed weight revealed that application of organic and inorganic amendments significantly influenced 1000-seed weight of maize hybrids. The interaction of maize hybrids with organic and inorganic amendments also showed significant results. Table 2 depicts that the maximum 1000-seed weight (257 g) was in hybrid Pioneer-30k08Y, followed by (239 g) maize hybrid Pioneer-3025W. Among the organic and inorganic amendments, the maximum 1000-seed weight (271.2 g) was achieved with farmyard manure application, closely followed by poultry manure (268.9 g), while the minimum (225.8 g) was recorded under control conditions. Concerning the interaction, Figure 9 showed that the highest 1000-seed weight (278 g) was observed in maize hybrid Pioneer-30k08Y with application of farmyard manure, followed by (274.7 g) in hybrid Pioneer-30k08Y with application of poultry manure, whereas the minimum 1000-seed weight (213.6 g) was observed in control treatments on maize hybrid Pioneer-3025W.

Grain yield (kgha^{-1}):

Grain yield was significantly affected by maize hybrids, treatment application, and their interaction (Table 2). Maximum grain yield (8112.9 kgha^{-1}) was recorded in maize hybrid Pioneer-30k08Y, whereas the lowest grain yield (4946 kgha^{-1}) was recorded in maize hybrid Pioneer-3025W. With respect to treatment application, the highest grain yield (7727.4 kg ha^{-1}) was obtained with farmyard manure, followed by poultry manure and inorganic fertilizer, which produced statistically similar yields. Whereas the lowest grain yield was recorded in the control treatments. Figure 10 depicts the interaction of maize hybrids and the application of organic and inorganic amendments for grain yield. Maximum grain yield was recorded with the application of farmyard manure on hybrid Pioneer-30k08Y; statistically similar results were observed in hybrid Pioneer-30k08Y with the application of poultry manure. Whereas the minimum grain yield was recorded in hybrid Pioneer-3025W under controlled treatments.

Biological yield (kg ha^{-1}):

Analysis of variance for biological yield (kg ha^{-1}) revealed that application of organic and inorganic amendments significantly influenced the biological yield (kg ha^{-1}) of maize hybrids. The interaction of maize hybrids with organic and inorganic amendments also showed significant results. Table 2 depicts that the maximum biological yield (19914 kg ha^{-1}) was in the hybrid Pioneer-30k08Y, followed by (18697 kg ha^{-1}) maize hybrid Pioneer-3025W. Regarding organic and inorganic amendments, the highest biological yield (21125 kg ha^{-1}) was observed with the application of poultry manure, followed by (21010 kg ha^{-1}) farmyard manure application, whereas the lowest biological yield (17461 kg ha^{-1}) was recorded in the control. Regarding the interaction (Figure 11), the highest biological yield (22,070 kg ha^{-1}) was recorded in maize hybrid Pioneer-30K08Y with poultry manure application, followed by a statistically similar yield (21,956 kg ha^{-1}) with farmyard manure in the same hybrid. In contrast, the lowest 1000-seed weight (213.6 g) was observed in the control treatment of maize hybrid Pioneer-3025W.

Table 2. Effect of organic and inorganic amendments on the Relative water content (%) of maize hybrids

Hybrids	Relative water content	Chlorophyll a	Chlorophyll b	1000-seed weight	Grain yield	Biological yield
Pioneer-30K08Y	73.33 a	1.46 a	0.64 a	257.04 a	8112.9 a	19914 a
Pioneer-3025W	69.15 b	1.17 b	0.42 b	239.92 b	6946 b	18697 b
LSD (0.05)	**1.13**	**0.02**	**0.02**	**0.88**	**15.4**	**46.86**
Treatments						
T0= control	63.88 f	0.98 g	0.29 j	225.82 j	7306.5 f	17461 j
T1= Compost	66.21 ef	1.4 d	0.56 e	256.68 d	7521.9 d	20037 d
T2= Farmyard Manure	83.58 a	1.57 b	0.61 d	271.2 a	7727.4 a	21010 b
T3= Poultry Manure	80.5 b	1.49 c	0.66 c	268.93 b	7690.7 b	21125 a
T4= Biochar	75.76 c	1.28 e	0.54 f	244.87 f	7574.7 c	19348 f
T5= Bio Fertilizer	67.01 e	1.26 e	0.71 b	250.43 e	7588.4 c	19720 e
T6= NPK	74.85 c	1.66 a	0.74 a	264.1 c	7668.9 b	20378 c
T7 Foliar application of Moringa leaf extract	70.68 d	1.58 b	0.52 f	244.88 f	7515.5 d	18753 g
T8= Salicylic Acid	67.35 e	1.08 f	0.44 g	234.67 h	7405.9 e	18315 h
T9 Indole Acetic Acid	66.98 e	1.06 f	0.36 i	231.38 i	7403.3 e	17861 i
T10= IBA (Indole Butric Acid)	66.85 e	1.09 f	0.39 h	240.3 g	7420.7 e	18353 h
LSD (0.05)	**2.65**	**0.49**	**0.02**	**2.08**	**36.12**	**109.9**
Interaction (hybrids x treatments)	Figure 6	Figure 7	Figure 8	Figure 9	Figure 10	Figure 11

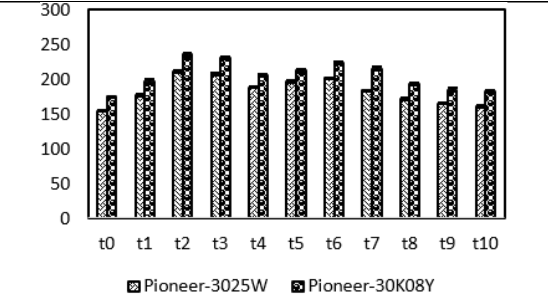

Figure 1. Effect of organic and inorganic amendments on plant height (cm) of maize hybrids

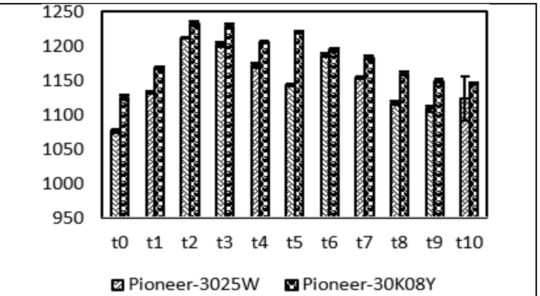

Figure 2. Effect of organic and inorganic amendments on leaf area (cm^2) of maize hybrids

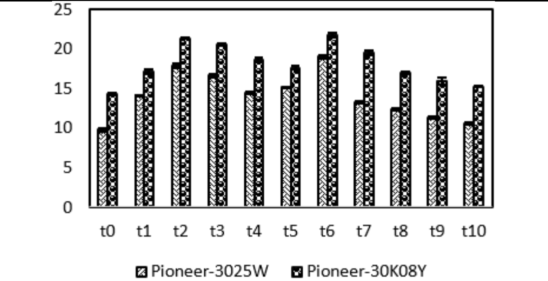

Figure 3. Effect of organic and inorganic amendments on Photosynthetic rate (µmole $m^{-2}s^{-1}$) of maize hybrids

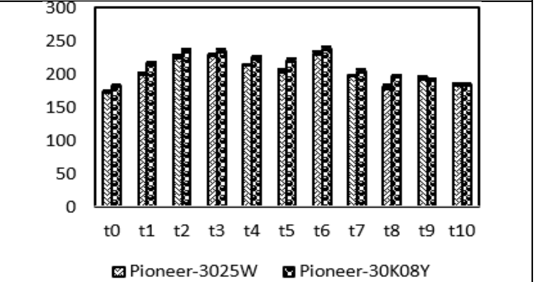

Figure 4. Effect of organic and inorganic amendments on Stomatal conductance (mmole m^{-2} s^{-1}) of maize hybrids

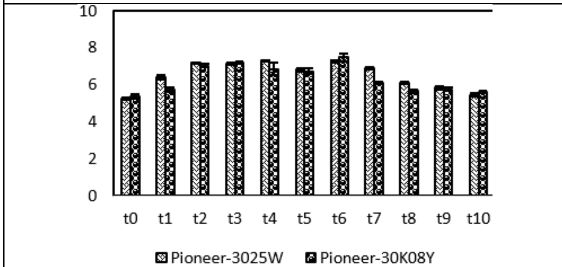

Figure 5. Effect of organic and inorganic amendments on transpiration rate (mmole m^{-2} s^{-1}) of maize hybrids

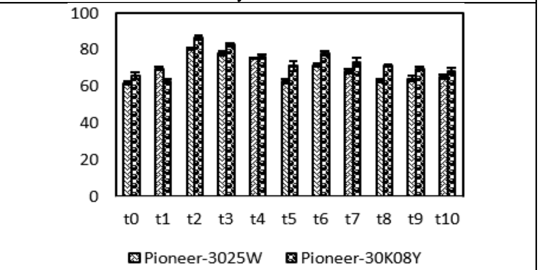

Figure 6. Effect of organic and inorganic amendments on the Relative water content (%) of maize hybrids

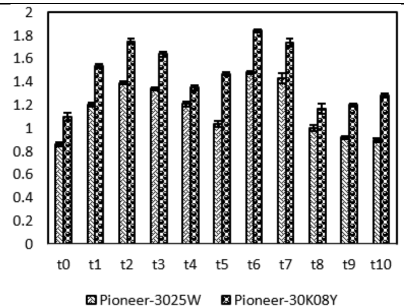

Figure 7. Effect of organic and inorganic amendments on Chlorophyll a (mg g^{-1}) of maize hybrids

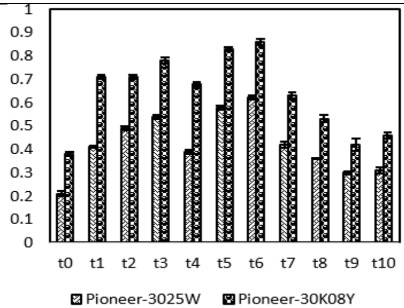

Figure 8. Effect of organic and inorganic amendments on Chlorophyll b (mg g^{-1}) of maize hybrids

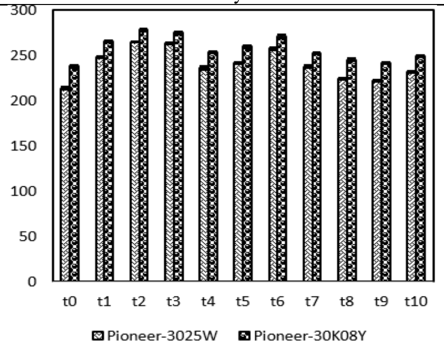

Figure 9. Effect of organic and inorganic amendments on 1000-seed weight (g) of maize hybrids

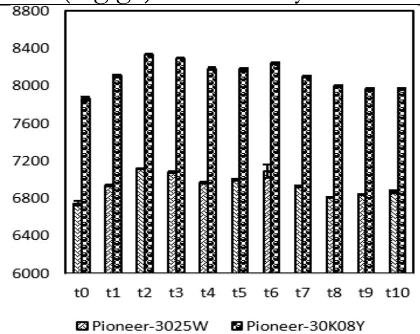

Figure 10. Effect of organic and inorganic amendments on grain yield (kg ha^{-1}) of maize hybrids

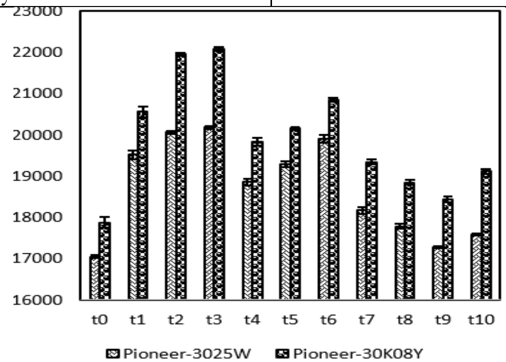

Figure 11. Effect of organic and inorganic amendments on biological yield (kg ha^{-1}) of maize hybrids

Discussion:

The use of organic manure in soil is increasingly important, as it enhances soil fertility while promoting crop growth and yield. These findings are consistent with those of Agegnehu et al. [23] and Abdelsalam [24], who found that adding compost (5 ton/ha) to maize enhanced crop productivity in terms of yield and yield components. Composting is an efficient nutrient management method for maintaining nitrogen absorption and maize yields, reducing nitrogen loss, and increasing soil fertility [25][26][27]. Organic additions can boost crop development by increasing nutrient availability in the soil [28]. Boateng *et al.* [29] reported that the maximum leaf area was recorded with farmyard manure application. A group of researchers also backed this work, Aziz *et al.* [30]. The reduced development might have been caused by a lack of nitrogen in the control group [31], which reduced plant height and leaf area in maize hybrids [32], but higher leaf area from farm yard manure might be due to easily accessible nitrogen to plants, which enhanced plant morphological growth [33]. Among essential nutrients, maize has a particularly high demand for nitrogen to support its optimal vegetative and reproductive development. Many physiological processes related to maize development are aided by the addition of nitrogen. Correia *et al.*, [34] confirm the connection between N nutrition and maize photosynthesis.

The photosynthetic rate and stomatal conductance of the control and organic fertilizer treatments were lower than in the inorganic manure treatments, according to Efthimiadou *et al.* [35]. Choudhary *et al.* [34] found that when maize plants were given nitrogen, their stomatal conductance and transpiration rate rose. Efthimiadou *et al.* [36] also discovered a strong link between photosynthetic rate and dry weight. The observed increase in photosynthesis may be attributed to improved nitrogen uptake by plants [37].

According to Doan *et al.* [38], significant differences in relative water content due to organic amendments can be clearly shown in water stress conditions. However, for the case of this study, irrigation was evenly distributed across the experiment, which likely explains the better performance. Mukta *et al.* [39] have reported better performance of organic manures than inorganic fertilizers regarding relative water content.

The use of inorganic fertilizers in several crops has been linked to an increase in leaf pigment content [40][41][42]. This effect may be attributed to the presence of essential minerals in manure, particularly micronutrients such as magnesium and iron, which play a vital role in chlorophyll synthesis [43]. Manure also includes plant growth hormones, increased amounts of soil enzymes, and many soil microbial communities. The application of FA has been reported to enhance leaf chlorophyll content in both maize and soybean [44]. In addition to its positive effects on soil physicochemical properties and overall plant growth, certain components of FA, once absorbed by plants, may directly stimulate pigment production in the leaves.

Treatment had a stronger influence on maize chlorophyll "a" concentration than on chlorophyll "b." Nutrient sources considerably increased chlorophyll "b" content. Chlorophyll "a" made up the majority of the total chlorophyll in the crops. This backed our previous findings that inorganic fertilizers released nutrients faster than organic manures. As a result, nutrients were accessible to enhance the photosynthetic site, promoting crop yield development [45]. The increase in thousands of grains might be attributed to a surplus of nutrients. According to Ibrahim et al. [46], improved nutrition management will enhance the weight of a thousand grains. The application of FYM to the crop resulted in a maximum thousand-grain weight. This might be because farmyard waste contains the most critical elements for seed and fruit development. Ahmed *et al.* [47] reported that the maximum thousand-grain weight was generated by farmyard manure application, which might be related to improved root growth and nutrient absorption from the soil. In comparison to the hybrid Pioneer-3025W, the hybrid Pioneer-30k08Y generated the highest thousand-grain weight. This discrepancy in both hybrids might be due to their responses to environmental factors.

Grain yield is determined by several contributing factors, including the number of cobs per plant, grain rows per cob, and thousand-grain weight. These parameters are directly influenced by the crop's genetic makeup, along with agro-management practices and climatic conditions during its growth and development stages.

According to Azimi et al. [48], organic manure treatment produces the maximum seed production, whereas non-application of biofertilizers produces the lowest seed yield. The application of biofertilizer increased grain production and biomass yield, which is a significant advantage, resulting in a decrease in production inputs because of saving money on chemical fertilizers and an increase in yield and biological yield [49]. Mixed treatments improve plant vegetative development, resulting in increased production in crops and legumes under farm settings, according to findings from many other studies [50].

These findings are consistent with those of [51], who found that applying farmyard manure and poultry manure increased grain weight, grain production, and straw yield. The increase in biological yield of maize after fertilizing the plots with 50% FYM might be attributed to the plants receiving an adequate and balanced supply of nutrients throughout their growth period.

Conclusion and Recommendation:

From this study, it can be concluded that the application of farmyard manure and maize hybrid produced higher seed yield under the agroclimatic conditions of Haripur. Hence, it is recommended to use the maize hybrid Pioneer-30k08Y and the application of organic manure for obtaining the maximum yield of the maize crop.

As the crop is undoubtedly suitable for Haripur, there is a need to evaluate various maize varieties in different farming situations across Haripur. There is also a need to study the performance of the crop in various stress conditions in the context of economic viability. Additionally, augmenting yield during this period with any agronomic measures like additional nutrition, plant densities, a combination of organic and inorganic fertilizers, etc., may be explored.

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