Research Article

Impact of integrated potassium management on plant growth, dry matter partitioning and yield of different maize (*Zea mays* L.) hybrids

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Abstract

Field experiment was conducted to investigate the impact of hybrids (DK-Garanon, Pioneer-3025, WS-666 and Pioneer-3164) and potassium ratios (100% organic, 80% organic + 20% inorganic, 60% organic + 40% inorganic, 40% organic + 60% inorganic, 20% organic + 80% inorganic, 100% inorganic and control treatment) on plant growth, dry matter partitioning and yield of maize crop during summer 2016. Poultry manure (PM) was used as organic source while sulphate of potash (SOP) as inorganic source of K (applied @ of 80 kg ha⁻¹). The results revealed that highest single leaf area (402.7 cm²), leaf area index (4), total dry matter plant⁻¹ (338.6g), stem weight plant⁻¹ (76.8g), leaves weight plant⁻¹ (45.1g), ears weight plant⁻¹ (187.3g), biological yield (14901 kg ha⁻¹) and grain yield (4898 kg ha⁻¹) were recorded for DK-Garanon hybrid. Regarding potassium ratios highest single leaf area (422.5 cm²), leaf area index (4.14), total dry matter plant⁻¹ (368.3g), stem weight plant⁻¹ (83.6g), leaves weight plant⁻¹ (52.3g), ears weight plant⁻¹ (203.8g), biological yield (15213 kg ha⁻¹) and grain yield (5362 kg ha⁻¹) were recorded in plots which received potassium ratio (40% organic + 60% inorganic) followed by plots which received K ratio (60% organic + 40% inorganic) while lowest values for the studied traits were recorded in control plot. It can be concluded from the experiment that application of K @ of 80 kg ha⁻¹ from both organic and inorganic sources at the ratio of (40% organic + 60% inorganic) to hybrid DK-Garanon resulted in higher yield.

Keywords: Dry matter plant⁻¹; Grain yield; Leaf area; Leaf area index; Poultry manure; Sulphate of potash

Introduction

Potassium (K) is deficient in many soils of Pakistan [1] because its application is negligible and the reserved K in soils is declining rapidly due to intensive cropping system [2]. Potassium deficiency considerably reduces photosynthetic

activity [3] which results in lower yield of maize [4]. Potassium increases nutrients and water transport [5], leaf area and leaf area index [6], crop growth rate [7], net assimilation rate [8] thus resulted in higher total dry matter production per unit area. Up to a certain limit K application

increases yield but beyond that limit it has a suppressive effect on plant growth, development and final yield [9]. Integration of organic and inorganic fertilizers along with proper application time increase yield of crops up to 60% [10]. Poultry manure is one of the important organic fertilizers that restore both macro and micro nutrients depleted from soil due to intensive cropping system [11].

Response of hybrids to potassium application varies because of variation in their uptake, translocation, accumulation, growth and utilization [12]. Efficient plant cultivar has higher nutrient use efficiency [13] and thus reduces cost of production and conserve environment [14]. Many physiological aspects like root morphology, root proliferation, root exudates, translocation and substitution of nutrients are the characteristics that lead to the overall variability among genotypes for K uptake and efficiency [14]. The present study was therefore initiated to investigate the effect of different hybrids and integrated K application on plant growth, dry matter partitioning to different organs, biological yield, and grain yield of maize crop.

Materials and methods

Field experiment was conducted to find the effect of hybrids (DK-Garanon, Pioneer-3025, WS-666 and Pioneer-3164) and potassium ratios (100% organic, 80% organic + 20% inorganic, 60% organic + 40% inorganic, 40% organic + 60% inorganic, 20% organic + 80% inorganic, 100% inorganic and control treatment) on plant growth, dry matter partitioning, biological yield and grain yield of maize. Poultry manure (PM) was used as organic source while sulphate of potash (SOP) was used as inorganic source of potassium applied @ of 80 kg ha⁻¹. Poultry manure was applied to the field three weeks before sowing of maize. The research was carried out at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2016. Soil of experimental site

was alkaline (pH 8.02), calcareous (CaCO₃>3%) in nature, low in organic matter (0.845 g kg⁻¹), non-saline (EC (1:1) 0.87 d S m⁻¹), low in available nitrogen (0.04 g kg⁻¹), phosphorous (4 mg kg⁻¹) and potassium (80 mg kg⁻¹). The texture of the soil was silty clay loam having 40% clay, 51.3% silt and 8.7% sand. [15]. The climate of the area is semiarid where the mean annual rainfall is very low (300 to 500 mm) with 60–70% rainfall occurs in summer while the remaining 30–40% rainfall occurs in winter [16]. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement having four replications. A subplot size of 3 m x 3.5 m was used. Each plot consisted of five rows, 3 m long and 0.7 m apart from each other. Nitrogen (N) and Phosphorous (P) added to the soil from poultry manure was calculated and the rest of N and P was fulfilled from Urea and DAP (di-ammonium phosphate) to provide a total of 150 and 90 kg ha⁻¹ N and P respectively. Data were recorded on plant growth parameters (single leaf area and leaf area index), total dry matter plant⁻¹ and dry matter partitioning towards stem, leaf, ear and husk at physiological maturity, biological yield and grain yield. Data for single leaf area was recorded by measuring leaf length and width of all leaves present at silking from five sampled plants, averaged and then multiplied. The obtained value was multiplied with correction factor (0.75 for maize) to get single leaf area. Leaf area index was calculated as leaf area divided by ground area. Total dry matter plant⁻¹ and dry matter partitioning was determined at physiological maturity stage. Five random plants were selected from each experimental unit and sun dried to a constant weight. All plants were weighed on electronic balance and their weight was averaged for measuring total dry matter plant⁻¹. The leaves, stem, ears and husks were separated from all plants and weighed separately on electronic balance which was then averaged to determine dry

weight of leaf, stem, ears and husk plant⁻¹. Data on biological yield was recorded by harvesting three central rows in each plot, the plants were sun dried for several days and weighed in the field with a balance to determine biological yield plot⁻¹. The data was then converted into kg ha⁻¹. Ears from the plants already harvested for biological yield were detached and shelled. The grains obtained were cleaned, weighed and converted into grain yield (kg ha⁻¹).

Meteorological data of the experimental site during the conduction of experiment are given in Figure 1. All the recorded data were statistically analyzed according to analysis of variance technique used for randomized complete block design with split plot arrangement. Means were compared using Least Significant Difference (LSD) test at 5% significance level in case of significant F-test through the procedure outlined by [17].

Figure 1. Total rainfall (mm) and mean maximum and minimum temperature (°C) for crop growth period in Peshawar (Pakistan Meteorological Department)

Results

Single leaf area

Single leaf area (cm²) was significantly ($P \leq 0.05$) affected by both hybrids and potassium ratios (Table 1). However, interaction of hybrids and potassium ratios was found non-significant. Among hybrids highest single leaf area was recorded for DK-Garanon hybrid followed by Pioneer-3025 while lowest single leaf area was recorded for WS-666 hybrid. In case of potassium ratios, the highest single leaf area was recorded in plots which were treated with potassium (40% organic + 60% inorganic) followed by potassium ratio (60% organic + 40% inorganic) with no statistical difference while lowest single leaf area was recorded in control plot.

Leaf area index

Hybrids (H) and potassium ratios (K) significantly ($P \leq 0.05$) affected leaf area index of maize crop (Table 1). Interaction of H x K remained non-significant for leaf area index. Mean values across potassium

ratios indicated that among hybrids highest leaf area index was recorded for DK-Garanon which was significantly different from other hybrids while lowest leaf area index was recorded for WS-666 hybrid. Planned mean comparison of potassium ratios indicated that plots which received K 40% from organic and 60% from inorganic sources produced highest leaf area index which was statistically similar with plots received K 60% from organic and 40% from inorganic sources while lowest leaf area index was recorded in control plot.

Biological yield (kg ha⁻¹)

Significant variations in biological yield was recorded for different maize hybrids and potassium ratios, while interaction between H and K was also found significant ($P \leq 0.05$) for biological yield (Table 1). Highest biological yield was recorded for DK-Garanon hybrid followed by Pioneer-3025, while lowest biological yield was recorded for WS-666 hybrid.

Planned mean comparison for potassium ratios indicated that highest biological yield was produced in plots which received K 40% from organic and 60% from inorganic source, while lowest biological yield was recorded in control plot. Interaction of H x K for biological yield of maize (Figure 2) indicated that highest biological yield was recorded for DK-Garanon hybrid when potassium was applied at the ratio (40% organic + 60% inorganic) while lowest biological yield was recorded for WS-666 hybrid in control plot.

Grain yield (kg ha⁻¹)

Grain yield of maize was significantly ($P \leq 0.05$) affected by different hybrids and potassium ratios (Table 1). However, H x K interaction was also found significant for grain yield. Mean values indicated that

highest grain yield was recorded for DK-Garanon followed by Pioneer-3025 hybrid which was statistical at par with Pioneer-3164 while lowest grain yield was recorded for WS-666 hybrid. Mean values across hybrids showed that among potassium ratios highest grain yield was recorded in plot which received K 40% from organic and 60% from inorganic sources followed by plot which received K 60% from organic and 40% from inorganic sources, while lowest grain yield was recorded in control plot. Interaction of H x K for grain yield of maize (Figure 3) showed that highest grain yield was recorded for DK-Garanon hybrid with application of potassium at the ratio of (40% organic + 60% inorganic) while lowest grain yield was recorded for WS-666 hybrid in control plot.

Table 1. Single leaf area (cm²), leaf area index, biological yield (kg ha⁻¹) and grain yield (kg ha⁻¹) of different maize hybrids as influenced by integrated potassium management.

Treatments	Single leaf area (cm ²)	Leaf area index	Biological yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)
Hybrids (H)				
DK-Garanon	402.7 a	4 a	14901 a	4898 a
Pioneer-3025	382.4 b	3.64 a	14008 b	4445 b
WS-666	352.4 c	3.04 b	13075 c	3967 c
Pioneer-3164	375.3 b	3.82 a	13785 b	4351 b
LSD_(0.05)	15.36	0.46	590.26	181.5
Potassium Ratios (P)				
100% organic	360.1 c	3.36 cd	13316 d	4038 d
80% organic+ 20% inorganic	359.2 c	3.33 d	13229 de	3966 d
60% organic+ 40% inorganic	403.9 a	3.80 b	15030 ab	4992 b
40% organic+ 60% inorganic	422.5 a	4.14 a	15213 a	5362 a
20% organic+ 80% inorganic	382.4 b	3.70 bc	13965 cd	4470 c
100% inorganic	383.9 b	3.86 ab	14296 bc	4653 c
Control	337.6 d	3.19 d	12547 e	3427 e
LSD_(0.05)	18.92	0.37	752.29	256.51
H x P interaction	ns	ns	**	**

Means of the same category followed by different letters are statistically different at 5% level of probability. ns= Non-significant ** = Significance at 1% level of probability

Figure 2. Interaction of hybrids and potassium ratios for biological yield (kg ha⁻¹) of maize crop

Figure 3. Interaction of hybrids and potassium ratios for grain yield (kg ha⁻¹) of maize crop

Dry matter partitioning (total dry matter plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and ears weight plant⁻¹)

Total dry matter plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and ears weight plant⁻¹ was significantly ($P \leq 0.05$) affected by hybrids and potassium ratios while husk weight plant⁻¹ and H x K interaction was found non-significant (Table 2). Planned means comparison for hybrids showed that among hybrids highest total dry matter plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and ears weight plant⁻¹ was recorded for DK-Garanon hybrid followed by Pioneer-3025, Pioneer-3164 while lowest total dry matter plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and

ears weight plant⁻¹ was recorded for WS-666 hybrid. Mean values across hybrids showed that highest total dry matter plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and ears weight plant⁻¹ was recorded in plots which received potassium 40% from organic and 60% from inorganic source followed by plots which received potassium 60% from organic and 40% from inorganic source while lowest total dry matter weight plant⁻¹, stem weight plant⁻¹, leaves weight plant⁻¹ and ears weight plant⁻¹ was recorded in control plot.

Discussion

Maize hybrids showed significant variations in single leaf area and leaf area index. Different genotypes respond differently to potassium application due to

variation in their uptake, translocation, utilization and accumulation of K [12]. Potassium significantly improved the crop growth variables like single leaf area and leaf area index. This might be due to the activation of several enzymes, increase in protein synthesis, N uptake and utilization that leads to better growth and development of maize and hence single leaf area and leaf area index was increased [8]. Our results are similar with the findings of [18] who reported that increasing fertilizer levels increased single leaf area and leaf area index because of increased amount of cellular constituents, mainly protoplasm, also increase in photosynthesis rate, cell division, cell enlargement, cell multiplication and cell differentiation significantly increase single leaf area and leaf area index.

Biological yield showed different response to various hybrids and potassium ratios. Maize hybrids significantly differ from each other regarding biological yield possibly due to variation in their genetic potential and various traits like plant height, leaf area, leaves plant⁻¹ and ears plant⁻¹ which contribute in the final biological yield. Potassium application increases biological yield of maize crop [19]. This might be due to the higher rate of CO₂ assimilation, stability in stomatal regulation and enzyme activity due to K which results in more carbohydrate production thus increased biological yield [20]. Also synergistic effect of organic and inorganic fertilizers leads to enhanced crop growth with the production of more biological yield. [4] Reported that integrated use of fertilizers resulted in higher biological yield of crop and it might be due to the availability of additional nutrients which led to higher biological yield. [21] Documented lowest biological yield when no fertilizers are applied while highest biological yield is obtained through integrated (organic and inorganic) use of fertilizers due to their synergy.

Grain yield showed profound variation for different hybrids and potassium ratios. [22] Indicated that different hybrids react differently for grain yield due to difference in their genetic makeup and potential expressed in terms of difference in ears plant⁻¹, grains ear⁻¹, rows ear⁻¹ and 1000 grains weight. Application of potassium significantly increased grain yield. The possible reason for higher grain yield in case of integrated K management might be the result of balanced supply of nutrients from organic and inorganic potassium sources. [23] Reported that use of 50% inorganic fertilizer in combination with 50% poultry manure resulted in higher maize grain yield when compared to 100% organic or inorganic sole fertilizer application. [24] revealed that higher maize grain yield was achieved when manure + inorganic fertilizers were practiced. [22] Reported that application of potassium increases maize yield.

The total dry matter plant⁻¹, stem weight plant⁻¹, ear weight plant⁻¹ and leaves weight plant⁻¹ of maize was different for various hybrids and potassium ratios. It might be due to differences in uptake of nutrients, growth rate, translocation, utilization and accumulation of assimilates among the hybrids. [25] Reported that dry matter production in stem, leaves, and ears of maize hybrids is significantly different from each other due to their different genetic potential. Dry matter partitioning increased with potassium application [25]. Balanced supply of nutrients from integrated (organic and inorganic) potassium application might be the reason for higher dry matter production. Application of K increases enzymes activation, photosynthesis and transport of sugars [26], stomatal activity, water and nutrients transport [5], protein and starch synthesis [27], leaf area [6, 28], crop growth rate [7, 29] and net assimilation rate [30] which further resulted in higher total dry matter production.

Table 2. Total dry matter plant⁻¹ (g), leaves weight plant⁻¹ (g), stem weight plant⁻¹ (g), ear(s) weight plant⁻¹ (g) and husk weight plant⁻¹ (g) of different maize hybrids as influenced by integrated potassium management

Treatments	Total dry matter plant ⁻¹ (g)	Leaves weight plant ⁻¹ (g)	Stem weight plant ⁻¹ (g)	Ear(s) weight plant ⁻¹ (g)	Husk weight plant ⁻¹ (g)
Hybrids (H)					
DK-Garanon	338.6 a	45.1 a	76.8 a	187.3 a	29.1
Pioneer-3025	312.0 b	40.4 b	72.3 b	170.9 b	28.3
WS-666	289.5 c	34.8 c	66.5 c	159.9 c	28.2
Pioneer-3164	305.1 b	38.6 b	69.8 b	169.1 b	27.4
LSD(0.05)	11.33	2.15	3.22	6.4	ns
Potassium Ratios (P)					
100% organic	290.1 d	35.0 d	67.0 d	159.6 d	28.2
80% organic+ 20% inorganic	281.9 d	33.5 d	65.0 d	157.3 d	25.9
60% organic+ 40% inorganic	343.6 b	46.5 b	78.2 b	189.0 b	29.8
40% organic+ 60% inorganic	368.3 a	52.3 a	83.6 a	203.8 a	28.5
20% organic + 80% inorganic	310.5 c	39.2 c	71.1 c	172.0 c	28.1
100% inorganic	317.7 c	41.0 c	73.0 c	174.4 c	29.3
Control	267.1 e	30.6 e	61.6 e	146.6 e	28.1
LSD(0.05)	12.1	2.25	3.12	7.91	ns
H x P interaction	ns	ns	ns	Ns	ns

Means of the same category followed by different letters are statistically different at 5% level of significance. ns= non-significant

Conclusion

The present study concluded that DK-Garanon hybrid produced highest grain yield as compared to Pioneer-3025, Pioneer-3164 and WS-666. Regarding potassium ratios, highest grain yield was recorded in plots which received potassium 40% from organic (poultry manure) and 60% from inorganic (sulphate of potash) source followed by plots which received potassium 60% from organic and 40% from inorganic source while lowest grain yield was recorded in control plots. Therefore, application of potassium @ of 80 kg ha⁻¹ from both organic and inorganic source at the ratio of 40:60 to hybrid DK-Garanon is recommended for achieving higher maize yield.

Authors' contributions

Conceived and designed the experiments: AA Khan & MF Jan, Performed the experiments: MF Jan, H Ahmad & W Liaqat, Analyzed the data: MF Jan & W Liaqat, Contributed materials/ analysis/ tools: MD Ahmadzai, H Ahmad & J Haroon, Wrote the paper: MF Jan, W Liaqat & H Ahmad.

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