Research Article

Response of Phenology, Growth and Productivity of Maize Hybrids to Integrated Potassium Management

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Abstract | Integrated application of nutrients from both organic and inorganic fertilizers is necessary for sustainable crop productivity. Field trial was performed at Agronomy Research Farm of The University of Agriculture Peshawar during summer 2016. Two factors were studied i.e. hybrids (DK-Garanon, Pioneer-3025, WS-666, and Pioneer-3164) and potassium ratios (Organic vs inorganic). The organic source includes poultry manure (PM) while inorganic source includes sulphate of potash (SOP). Potassium (K) was applied to field in such an arrangement that 100, 80, 60, 40, 20 and 0% K was obtained from the organic source and the remaining was balanced form inorganic source for supplying a total K of 80 kg ha^{-1}. Randomized complete block design with split plot arrangement was used. Hybrids were allotted to main plots and K ratios to subplot. Analysis of the data showed that crop phenology, growth, and yield of maize were significantly affected by both hybrids and potassium ratios. Maize hybrids and potassium ratios did differ in crop phenology (days to emergence, tasseling, silking, and maturity) and crop growth (single leaf area, leaf area index, and plant height) which resulted in different grain yield. Among hybrids DK-Garanon gave highest value for all the studied parameters as compared to others hybrids. Similarly, in K ratios higher values for the studied traits were recorded in plots which were treated with K 40% from organic (poultry manure) and 60% from inorganic (sulphate of potash) sources. It can be concluded that application of K at the rate of 80 kg ha^{-1} from both organic and inorganic sources at the ratio of 40% organic + 60% inorganic respectively to hybrid DK-Garanon resulted in higher net return from maize in terms of yield.

Received | March 19, 2018; **Accepted** | September 03, 2018; **Published** | October 29, 2018
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Citation | Jan, M.F., A.A. Khan, W. Liaqat, H. Ahmad, M.D. Ahmadzai and W. Rehan. 2018. Response of phenology, growth and productivity of maize hybrids to integrated potassium management. *Pakistan Journal of Agricultural Research,* 31(4): 306-312.
DOI | http://dx.doi.org/10.17582/journal.pjar/2018/31.4.306.312
Keywords | Poultry manure, Sulphate of potash, Days to maturity, Leaf area, Grain yield

Introduction

Nutrients recycling through use of organic fertilizers are an effective strategy for coping with nutrient consumption and promoting crop productivity and sustainability (Paul and Mannan, 2006). For sustainable crop production organic fertilizers have been used (Naeem et al., 2009). The integrated use of fertilizers improved soil organic matter, soil structure, soil health, soil pH, available micro and macro nutrients resulted in better crop productivity (Rautaray et al., 2003). In manures, poultry manure is the best source which contains large number of micro-organisms and nutrients and is beneficial for crop growth and development, resulted in higher crop productivity (Sims and Wolf, 1994).

Responses of cultivars are different to potassium (K), because of differences in their mode of uptake of nutrients, translocation, accumulation, growth and utilization (Minjian et al., 2007). Potassium use efficiency of different cultivars varies which reduce cost of inputs and conserve environment (Rengel and Damon, 2008; Baligar et al., 2001). Greater plasticity (Sparlangue et al., 2007), higher grain yield and harvest index stability are the characteristics of hybrids. The characteristics of hybrids are due to their genetic yield improvement attributes. Different genotypes have different potassium uptake and use efficiencies (Allan et al., 1998). Hybrids have greater potassium uptake which resulted in higher grain yield. Variation in grain yield among hybrids is due to many physiological aspects which can genetically lead to the overall variability in yield (Rengel and Damon, 2008).

Potassium (K) plays a vital role in life cycle of a crop and performed an energetic role in plant growth and development (Bukhsh et al., 2012). K increases leaf area (Meille and Pellerin, 2008; Rasheed, 2002), plant height (Pandey et al., 2000), enhances crop growth rate (Cassman et al., 1989), net assimilation rate (Akhtar et al., 1999), and increases grain yield (Pettigrew, 2008). K increases enzymes performance and photosynthesis (Van Brunt and Sultenfuss, 1998), carbohydrates and protein synthesis (Patil, 2011). K helps in energy metabolism, physiological processes such as xylem and phloem transport, uptake of nutrients, and osmoregulation (Thomas and Thomas, 2009). Application of organic K especially from poultry manure supplies all essentials nutrients and resulted in more grains ear^{-1} (Ayoola and Adeniyan, 2006). It has been found that organic potassium has increased quality and yield of maize (Giskin et al., 1984; Giskin and Efron, 1986). Rehman et al. (1982) and Krishnan (1977) concluded from their research that an application of 60 kg organic K_2O ha^{-1} is economical.

Thus, the aim of this research was to find out a suitable maize hybrid along with an appropriate potassium ratio from both organic and inorganic sources for achieving higher maize grain yield.

Materials and Methods

Field experiment was conducted at Agronomy Research Farm of the University of Agriculture, Peshawar during summer 2016. The ANOVA (Analysis of variance) used for the experiment was randomized complete block design with split plot arrangement. Two factors i.e. Hybrids (DK-Garanon, Pioneer-3025, WS-666, and Pioneer-3164) and potassium ratios i.e. organic (poultry manure) vs inorganic (Sulphate of potash) were studied. Hybrids were allotted to main plots and potassium ratios to subplots. Potassium was applied to field in such an arrangement that 100, 80, 60, 40, 20 and 0% potassium was acquired from the organic source and the remaining was compensated form inorganic source for supplying a total K of 80 kg ha^{-1}. The plot was 3 m long and 3.5 m wide having five rows 0.70 m apart from each other. Poultry manure was applied three weeks before sowing. Sowing was made on 15 July 2016. Nitrogen as a urea and phosphorus as a DAP (di-ammonium phosphate) was applied at the rate of 150 and 90 kg ha^{-1} respectively.

Observations and measurements

Data regarding days to emergence were recorded by counting the number of days from the date of sowing till 50% plants emerged in each experimental unit. Days to flowering was observed and recorded by counting the days from date of sowing to date when 50% plants produced flower (tassel or silk) in each experimental unit. Days to maturity was recorded by counting the days from sowing to date when 50% plants get physiological matured in each experimental unit. Maturity was indicated by black scar appeared at kernel base. Plant stature was measured with the help of a meter rod at physiological maturity. In each experimental unit five plants were randomly selected and measured from base to the tip of tassel. For leaf area data, five plants were randomly selected in each experimental unit at silking stage. Length and width of all leaves were determined and averaged for a single leaf area data. The leaf area obtained was then multiplied with the correction factor i.e. 0.75. Leaf area index (LAI) was calculated by multiplying total number of plants per unit area into average number of leaves per plant. The obtained data was then multiplied with average leaf area per plant to get LAI. Grain yield was recorded by harvesting plants from three rows of each experimental unit. Ears were detached from plants, dehusked, shelled and central dried for constant weight. After grains constant weight their weight was taken to calculate the grain yield. The grain yield was converted into kg ha $^{-1}$.

Statistical analysis of data

The data were statistically analyzed according to ANO-

VA (analysis of variance) used for RCB design (split plot arrangement) at 5% level of significance (P≤0.05) through statistix 8.1 software. Least significant difference (LSD) test was used upon significant F-test through the procedure designated by Jan et al. (2009).

Results and Discussion

Crop phenology plays an important role and contributes a lot to the yield of crop. Different hybrids (H) and Potassium ratios (K) significantly affected various phonological parameters of maize crop.

Days to emergence

Hybrids significantly differ in days to emergence while potassium ratios and their interaction remained non-significant for days to emergence of maize crop (Table 1). Among hybrids, more days to emergence were recorded for WS-666 hybrid whereas DK-Garanon hybrid took less days to emergence. Difference in hybrids regarding days to emergence might be due to difference in their germination percentage, viability, seed size, and seed vigour. Similar results were also reported by Tahir et al. (2008) and Minjian et al. (2007).

Days to tasseling and silking

Maize hybrids (H) and potassium ratios (PR) significantly affected days to flowering of maize crop (Table 1). Interaction of H x PR remained non-significant for days to flowering. Among hybrids, earlier tasselling and silking were observed for WS-666 hybrid which was significantly different from other hybrids whereas delayed tasseling and silking were recorded for DK-Garanon hybrid. Different researchers (Zamir, 1998; Modarres et al. (1998); Gozubenli, 2001) reported that variation in tasseling and silking period of maize hybrid is due to its genetic makeup. The shorter season hybrids took less time to tasseling than did the longer season hybrids. Tsai et al. (1996) and Bresolin et al. (1979) reported that tasseling period of different maize hybrids are different due to difference in their genetic potential. Similarly, Luque et al. (2006) and Liu et al. (2004) reported that difference in period of days to silking for different hybrids is different due to their genetic variation. In potassium ratios, delayed tasseling and silking were observed in control plots while earlier tasseling and silking were observed in plots which received sole inorganic potassium (SOP). Mahmood (1994) reported that application of potassium decreases the number of days to tasseling and silking in maize crop.

Table 1: *Effect of integrated potassium management on days to emergence, tasseling, silking, and physiological maturity of maize hybrids.*

Treatments	Days to emergence	Days to tasseling	Days to silking	Days to physiological maturity
Hybrids				
DK-Garanon	6 c	57 a	60 a	93 a
Pioneer-3025	7 b	55 b	58 b	92 b
WS-666	8 a	53 c	56 c	89 c
Pioneer-3164	7 b	55 b	58 b	92 b
LSD	0.21	1.33	1.21	1.15
Potassium Ratios				
100% organic	7	57 b	60 b	93 b
80% organic+ 20% inorganic	7	58 b	60 b	93 b
60% organic+ 40% inorganic	7	57 b	60 b	93 b
40% organic+ 60% inorganic	7	54 c	56 c	89 c
20% organic+ 80% inorganic	7	52 d	54 d	88 c
100% inorganic	7	51 d	54 d	88 c
Control	7	59 a	62 a	95 a
LSD	NS	1.17	1.17	1.26
Hybrids x Potassium ratios interaction	NS	NS	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability; **NS:** *Non significant.*

Days to physiological maturity

Physiological maturity was significantly affected by maize hybrids and potassium ratios however; interaction of hybrids and potassium ratios was non-significant (Table 1). Earlier maturity was observed for WS-666 hybrid which was significantly different from other hybrids while delayed maturity was observed for DK-Garanon hybrid. Similarly in potassium ratios, earlier maturity was recorded in plots which received sole inorganic potassium (SOP) while delayed maturity was observed in controls plots. Asif et al. (2007) reported that increase in potassium levels resulted in earlier physiological maturity as compared to control plots. Our findings are similar to the results of Liaqat et al. (2018) who documented that application of K significantly decreased days to phenology (days to tasselling, silking and maturity) in maize crop.

Single leaf area and leaf area index

Single leaf area and Leaf area index (LAI) was significantly affected by hybrids and potassium ratios (Table 2). However, interaction between hybrids and potassium ratios was found non-significant. Highest single leaf area and leaf area index was recorded for DK-Garanon hybrid which was significantly different from other hybrids while lowest single leaf area and LAI was recorded for WS-666 hybrid. Nawaz (2006) and Minjian et al. (2007) reported that different genotypes express differently to K application due to difference in their uptake, growth, translocation, utilization and accumulation of nutrients. Similarly in potassium ratios highest single leaf area and LAI were recorded in plots which were treated with potassium 40% from organic and 60% from inorganic sources while lowest single leaf area and LAI were recorded in control plots. Our outcomes are in line with those reported by Liaqat et al. (2018). Rao and Padmaja (1994) reported that increasing fertilizer levels increases amount of cellular constituent, mainly protoplasm, also increases photosynthetic rate, cell division, cell enlargement, cell multiplication and cell differentiation which significantly increased single leaf area and leaf area index.

Plant height (cm)

Plant height was significantly influenced by both maize hybrids and potassium ratios while hybrids and potassium ratios interaction remained non-significant (Table 2). Highest plant height was attained by DK-Garanon hybrid which was statistically different from others hybrids. It might be due to the difference in genetic makeup among hybrids. Umakanth and Satyanarayana (2000) reported that differences in plant height among hybrids are due to their genetic variations. Similarly, potassium ratios also caused significant variations in plant height. Highest plant height was recorded in plots which received potassium 40% from organic (poultry manure) and 60% from inorganic (SOP) sources while lowest plant height was recorded in control plots. It might be due to timely availability of nutrients from both organic and inorganic sources which resulted in taller plants. Makinde and Ayoola (2010) and Ayoola and Makinde (2007) reported that integrated use of fertilizers i.e. both organic and mineral significantly increased plant stature than sole fertilizer. Pandey et al. (2000) and Stone et al. (2001) reported that application of potassium significantly increased plant height.

Grain yield (kg ha^{-1})

Statistical analysis showed that grain yield was significantly affected by hybrids and potassium ratios (Table 2). However, interaction of hybrids and K ratios was non-significant. Highest grain yield was recorded for DK-Garanon hybrid which was significantly different

Table 2: *Response of single leaf area (cm^2), leaf area index, plant height (cm), and grain yield (kg ha^{-1}) of maize hybrids to integrated potassium management.*

Treatments	Single leaf area (cm^2)	Leaf area index	Plant height (cm)	Grain yield (kg ha^{-1})
Hybrids				
DK-Garanon	402.7 a	4.00 a	210.3 a	4898 a
Pioneer-3025	382.4 b	3.64 a	195.1 b	4445 b
WS-666	352.4 c	3.04 b	174.6 c	3967 c
Pioneer-3164	375.3 b	3.82 a	190.5 b	4351 b
LSD	15.36	0.46	11.07	181.5
Potassium Ratios				
100% organic	360.1 c	3.36 cd	181.2 d	4038 d
80% organic+ 20% inorganic	357.1 c	3.30 d	178.0 d	3966 d
60% organic+ 40% inorganic	403.9 a	3.73 b	223.0 a	4992 b
40% organic+ 60% inorganic	422.5 a	4.14 a	210.1 b	5362 a
20% organic+ 80% inorganic	382.4 b	3.70 bc	193.6 c	4470 c
100% inorganic	383.9 b	3.86 ab	196.3 c	4653 c
Control	337.6 d	3.29 d	166.0 e	3427 e
LSD	18.92	0.37	11.26	256.51
Hybrids x Potassium ratios interaction	NS	NS	NS	NS

Means of same categories followed by different letters are statistically different at 5% level of probability; **NS:** *Non significant.*

from other hybrids. Pettigrew (2008) and Damon and Rengel (2008) concluded that different hybrids react differently regarding grain yield due to their genetic makeup and potential expressed in terms of difference in ears plant^{-1}, number of grains cob^{-1} and 1000 grains weight. Similarly, in potassium ratios the highest grain yield was recorded in plots which received potassium 40% from organic (Poultry manure) and 60% from inorganic (SOP) sources while lowest grain yield was recorded in control plots. It might be due to balanced supply of essential nutrients form organic and inorganic potassium sources which boost up plant growth and development resulted in higher grain yield. Our findings are supported by Liaqat et al. (2018) who reported that application of K significantly increased grain yield of maize. Similar result is reported by Zafar et al. (2011) who reported that integrated nutrients management from organic and inorganic sources is key to achieve the productivity on sustainable basis. This is also in agreement with the results of Rasool et al. (2008) who stated that combine use of nutrients from organic manure and commercial fertilizers resulted in higher yield.

Conclusion

From the experimental results it can be concluded that various maize hybrids and potassium rations showed significant variations in phenology, growth and yield. Among hybrids DK-Garanon produced highest grain yield than Pioneer-3025, WS-666, and Pioneer-3164. Similarly, potassium ratio 40% from organic and 60% from inorganic produced highest grain yield. Thus, application of source 80 kg ha^{-1} K from both organic and inorganic sources at the ratio of 40:60 is recommended for achieving higher maize yield.

Author's Contribution

Muhammad Faheem Jan and Asad Ali Khan designed the experiment. Muhammad Faheem Jan performed the experiment, collected data and wrote manuscript. Waqas Liaqat, Haseeb Ahmad and Muhammad Dawood Ahmadzai provided experiment inputs. Waqas Liaqat assisted Muhammad Faheem Jan in writing results and discussion. Wazir Rehan helped in writing introduction and abstract. Waqas Liaqat provided technical input in data entry and analysis.

Acknowledgement

The authors are thankful to the field staff of Agronomy Research Farm for their assistance during data collection and Department of Agronomy, University of Agriculture Peshawar, Pakistan for their grant to support the experiment.

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