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Effect of Phosphorus Application Methods on Growth and Yield of Maize under Water Deficit Conditions

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ABSTRACT

A field study was conducted to investigate effect of phosphorus and different levels of irrigation on growth and yield of maize at the Agronomic Research Area, Faculty of Agricultural sciences and Technology, Bahauddin Zakariya University, Multan, during autumn 2016.The Experiment was laid out in randomized complete block design (RCBD) with split plot courses of action having three replications with net plot size of 4m x 3m. The crop was sown in 75 cm spaced rows, while plant to plant distance was maintained at 30 cm with the help of dibbler. Experimental treatments comprised of two irrigation level sand four phosphorus levels. The crop was harvested at maturity and the data were recorded by using the standard procedures. Maximum grain yield was obtained at full irrigation levels where phosphorus was applied @ 100 kg ha^{-1}. All the growth and yield parameter increased with full irrigation levels with application of Phosphorus at the rate of 100 kg ha^{-1} while it was decreased where half irrigation was applied. Increase in P2O5 rates upto100 kg ha^{-1} enhanced the plant height, cob length, cob weight, thousands grain weight, Beyond application of 100 kg P2O5 ha^{-1} there was no significant increase in number of grains cob-1, thousand grain weight and other growth parameters. It is recommended that maize crop should preferably be fertilized @ 100 kg Phosphorus per hectare to get maximum grain yield under the ecological conditions of Multan.

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INTRODUCTION

Maize (*Zea mays* L.) is the highest yielding cereal in the world. It is from family Poaceae and has an important place in crop husbandry because of its high yield potential and short duration of growth. It engages third position in production next to wheat and rice used for food in the world (Farnia and Shafie, 2014). For industry, maize as a raw material is broadly used for the preparation of flakes, dextrose, cosmetics, oil, syrup, wax, starch, alcohol, while its tanning material is being used for leather production (Pakistan Agriculture Research Council, 2016). Grains are the major product of maize, which have greater oil and starch than other grains (Langer, 1991). Maize's ethanol can also be used as a biomass fuel. It is also being used as feed for livestock, forage and making silage after fermentation of corn stocks (Pakistan Agriculture Research Council, 2016). In Pakistan, maize contribution in total food grains production is about 6.4. It has high nutritional value as it contains about 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 1.7% ash (Chaudhary, 1993). During 2017-18, maize crop was cultivated on an area of 1,229 thousand hectares and witnessed decline of 8.8 percent over last year's cultivated area of 1,348 thousand hectares. Maize crop production recorded a decline of 7.0 percent as its production stood at 5.702 million tonnes compared to the last year's production of 6.134 million tones. Maize percent value added in agriculture and 0.5 percent to GDP. Maize originated from Mexico, and is mainly grown in the warmer temperate regions and humid sub-tropics. It is a C4 plant, which confers potentially more efficient use of CO_2, solar radiation, water and N in photosynthesis than C3 crops. Water use efficiency (WUE) of maize is approximately double that of C3 crops grown at the same sites. Its transpiration ratio (molecules of water lost per molecule of CO2 fixed) is 388, corresponding to 0.0026 in WUE (Jensen 1973), while that of wheat is 613, soybean 704. Maize has different responses to water deficit according to development stages (Cakir, 2004). Drought stress is particularly damaging to grain yield if it occurs early in the growing season (when plant stands are establishing), at flowering, and during mid to late grain filling (Heisey and Edmeades, 1999). At the seedling stage, water stress is likely to damage secondary root development. During stem elongation (after floral initiation) leaves and stems grow rapidly, requiring adequate supplies of water to sustain rapid organ development, water stressed plants being shorter and with reduced individual and cumulative leaf area (Muchow, 1989). The most critical period for water stress in maize is ten to fourteen days before and after flowering, with grain yield reduced two to three times more when water deficit coincides with flowering compared with other growing stages (Grant *et al*. 1989).

Maize has its origin in a semiarid area but it is not a reliable crop for growing under dry land conditions, with limited or erratic rainfall. Although maize grain yield has increased significantly, but still there is a big gap between potential yield and actual yield of different cultivars. Doorenbos and Pruitt (1983) reported that the water requirements of maize for maximum production varied between 430-490 mm per season depending on climate and length of growing period. Beside soil water status the climate has also a direct impact on plant growth and yield. Flood irrigation over the entire field results in leaching down the nitrates from the root zone causing loss of fertilizer and thereby reduces the final plant height, dry matter production, leaf area index and grain yield of maize. Both excessive and restricted supplies of water to crops are equally harmful and the adoption of effective irrigation application methods for crop production is required (Mahal *et al*., 2000).

Maize is an exhaustive crop having higher potential than other cereals and absorbs large quantity of nutrients from the soil during different growth stages. Among the essential nutrients, phosphorus is one of the most important nutrients for higher yield in larger quantity (Chen *et al*. 1994) and controls mainly the reproductive growth of plant (Wojnowska*et al*. 1995). Generally, P is the second most crop-limiting nutrient in most soils. It is second only to nitrogen in fertilizer use. Plant growth behavior is influenced by the application of phosphorus (Hajabbasi and Schumacher, 1994; Gill *et al*. 1995; Kaya *et al*. 2001). It is needed for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, fat and albumen formation. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction (Ayub*et al*., 2002).

Phosphorus nutrient deficiency is the norm in native soils and the imbalance affect large areas (Lynch and Clair, 2004). Many of the agricultural soils in the tropical and sub-tropical regions are deficient in both total and available P when compared with other macronutrients (Chien and Monion, 1995). Replenishment of soil P is often problematic as it is often fixed in soils with high sorption capacity rendering it less available. The deficiency of Phosphorus occurs widely in the tropics and it is so acute that plant growth stops because the seed reserve is quickly exhausted during germination (Jones and Wild, 1975). Deficiency of P is usually linked with low supply of available P, soil mineralogical properties and some chemical reactions which might lead to P fixed down.

From previous discussion it is hypothesized that phosphorus application methods can improve maize growth and yield under limited water supply.

METHODS AND MATERIAL

Experimental site and its design

This experiment was conducted check the effect of various application methods of phosphorus under water deficit conditions of maize during autumn 2017 at B.Z.U. Multan. The experimental area is situated at 71.4º E longitude, 30º N latitude and an altitude of 215 meters. The typical weather of this region is semiarid.

Chemical analysis of soil

The initial soil fertility amount was determined from the sample taken from experimental site before sowing the crop. The soil chemical test was performed in the soil chemistry laboratories of Soil Science and test report obtained was presented in the table 1.

Table 1 Chemical Analysis of Soil.

Determination	Unit	Value obtained
pH		8.2
Organic matter	%	0.93
Available S	Ppm	7.1
Available K	Ppm	172
Total N	%	0.19
Available phosphorus	Ppm	1.05

Experimental details

1. Two factors were studied;
2. Factor A = Irrigation Methods
3. I_1 = Half (50%) Irrigation
4. I_2 = Full (100%) Irrigation
5. Factor B = Phosphorus Methods (P_2O_5)
6. P_0 = control
7. P_1 = Seed application of DAP
8. P_2 = Foliar application of DAP
9. P_3 = Soil application of DAP

Observations recorded

The following observations were recorded during the course of study.

Pant height at maturity (cm)

Ten plants from each plot were selected at random and their heights were measured from soil surface to the final growing point with the help of a measuring tape and then average was taken.

Cob length (cm)

Lengths of ten cobs from each plot were measured and average was worked out.

Cob weight with sheath (g)

Ten cobs were taken randomly from each plot and weighed individually and then average was taken.

Cob weight without sheath (g)

Ten cobs were taken randomly from each plot and their sheaths were removed, weighed and their average was taken.

Cob diameter (cm)

Sheaths of ten randomly selected plants were removed. Diameter was taken with the help of verniercallipers from three points of the cob. Mean of these three readings was taken and then average of ten cobs was calculated.

Number of grain rows per cob

From ten cobs, selected randomly from each plot, the grain per row of each cob was counted and then average was calculated.

Number of grain rows per cob

From ten cobs, selected randomly from each plot, the grain rows of seeds were counted and then average was calculated.

Number of grains per cob

From ten cobs, selected randomly from each plot, grains of each cob were counted and then averaged.

1000-Grain weight (g)

A representative sample of grains was obtained from the produce of each plot, and then 1000-grains were counted manually and weighed on an electric balance.

Biological yield (t ha^{-1})

The crop was harvested at maturity, tied up into small bundles and left in their respective plots for few days. The dried bundles were weighed with the help of spring balance. Biological yield of each plot was taken and then converted in to t ha^{-1}.

Grain yield (t ha^{-1})

All the cobs from each net plot were separated from plants and shelled with the help of Sheller and weighed to have grain yield. Then grain yield was converted in to t ha^{-1}.

Harvest index (%)

Harvest index is the ratio of grain yield to the total biological yield expressed in percentage. It was calculated by the formula as under:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{Biological\ yield} \times 100$$

Layout

The Experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having three replications with net plot size of 4m x 3m.

Statistical Analysis

Data obtained from different parameters were analyzed statistically using Fishers Analysis of Variance Technique and least significant different test level by using (statistics 8.1) to compare differences among the treatments' means and LSD at (P=0.05).

RESULTS AND DISCUSSION

Effect of different P application methods with full and half irrigation on plant height of maize crop

Data about the plant height revealed that plant height become increase with increasing phosphorus application methods (table 2). Highest plant height (8.41 cm) was observed in soil application method conditions than the foliar phosphorus system(7.10cm) .This application methods also showed better plant height in water deficit at vegetative + reproductive stage (6.53 ft). In control phosphorus (P = 4.49cm) shortest plant height was observed in well irrigated as well as in water deficit at vegetative and reproductive stages. Better results were obtained in well irrigated phosphorus soil application methods whereas water deficit at vegetative and reproductive stages reported lowest plant height as compared to reproductive stage.

Plant height is very important component with respect to grain yield in maize crop. The reason is that if the plant will be healthy, ultimately effect on plant height. Taller plants contain more grain yields and biological yield. Soil phosphorus application method was best method with for the maize crop. Plant uptake more phosphorus as compared to other application methods of phosphorus. Other one, factor was the application of phosphorus with full irrigation. Proper irrigation enhanced the uptake capacity of phosphorus element in maize crop. It increased the dry matter accumulation, ultimately effect on plant height and crop growth. Soil phosphorus application method with full irrigation positively improved the physiological process. Our results were also in accordance to (Raju*et al*., 2015).

Table 2. Analysis of variance for plant height as influenced by different phosphorus levels of maize.

SOV	DF	Plant Height MS
Irrigation (I)	1	10.2835*
Phosphorus(P)	3	11.4935**
(I)*(P)	3	0.7809*
Total	7	

Table 3. Effect of different phosphorus methods on plant height (cm) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	4.4967e	4.1467e
P1(Seed Application)	6.200cd	4.3533e
P2(Foliar Application)	7.1000b	5.9433d
P3(Soil Application)	8.4167a	6.5333bc

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on cob length of maize crop

Results of analysis of variance showed significantly maximum cobs length with the application method of soil phosphorus at the rate in well irrigated conditions (table 4). With this application methods, water stress at vegetative and reproductive stages also reported better cobs length as compared to other phosphorus seed

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application method. Minimum cobs length was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus application method. Shortest cobs length was observed in water stress and well irrigated at vegetative and reproductive stage as compared to foliar and seed application methods. Better results were obtained in well irrigated field where increased cobs length was observed with increasing phosphorus application method of soil.Cob length is very important parameter and have direct effect on grain yield. The size of cob length indicate the yield of grains. Increase in size of cob results as increase in number of grains per ear. From results it was judged that application method of phosphorus in soil with proper irrigation enhanced the uptake of phosphorus for maize crop. There were maximum availability of nutrients in frequent irrigation. Due to proper supply of phosphorus, both the stages (vegetative + reproductive) were improved. By applying phosphorus in soil, there were some positive changes in cell division and cell enlargement. So, the size of cob was increased, ultimately grain yield was also increased. Same findings were obtained by (Iqbal and Chauhan, 2003).

Table 4. Analysis of variance for cobs Length as influenced by different phosphorus levels of maize.

SOV	DF	Cobs Length
Irrigation (I)	1	65.6704*
Phosphorus(P)	3	7.0104**
(I)*(P)	3	0.7982**
Total	7	

Table 5. Effect of different phosphorus methods cobs length (cm) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	7.3333b	3.4333g
P1(Seed Application)	8.2333b	4.4000f
P2(Foliar Application)	8.8667a	5.7000e
P3(Soil Application)	9.0000a	6.6667d

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on Fresh weight (g) of maize crop

Results of analysis of variance showed significantly maximum fresh weight 466.67 with the soil application of phosphorus in deficit irrigated conditions (table 6). With this seed application methods well irrigation at vegetative and reproductive stages also reported better fresh weight as compared to other phosphorus application techniques. Minimum fresh weight was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus (P = 247.67, 541.33 kg ha^{-1}) respectively. Shortest fresh weight was observed in well irrigation at vegetative + reproductive stage followed by reproductive stages. Better results were obtained in through soil application method where increased fresh weight was observed with increasing phosphorus application methods. Fresh weight of leaf, ear and stem was higher with foliar application than the seed application technique. The possible reason could be soil application phosphorous enabled the plants to absorb greater amount of the applied P resulting in more assimilate formation and partitioning to leaf, ear and stem. Arya and Singh (2001) found increased fresh weight accumulation in maize with soil application methods. Maximum leaf and ear fresh weight was noted in the fields that received P through foliar application was noted in the fields that received P at sowing time. Roman andWillium (1993) found that clay loam texture had maximum P fixation through the seed application methods has got proper amount of P availability, P-fertilizers should not be applied much before plantation to minimize P fixation through the different application methods of phosphorus.

Table 6. Analysis of variance for fresh weight as influenced by different phosphorus levels of maize.

SOV	DF	Fresh weight of plant
Irrigation (I)	1	28536*
Phosphorus(P)	3	21812*
(I)*(P)	3	9353*
Total	7	

Table 7. Effect of different phosphorus methods on fresh weight (g) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	541.33b	247.67f
P1(Seed Application)	605.0a	347.00e
P2(Foliar Application)	615.67b	406.00d
P3(Soil Application)	623.67a	466.67c

Effect of different P application methods with full and half irrigation on Dry weight (g) of maize crop

Results of analysis of variance showed significantly maximum dry weight (g) with the application methods of phosphorus at the well and deficit irrigated conditions (table 7). With this application method of soil water stress at vegetative and reproductive stages also reported better dry weight (g) as compared to other phosphorus application methods. Minimum dry weight (g) was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus application. Undeviating dry weight (g) was observed in water stress at vegetative andreproductive stage followed by reproductive stages. Better results were obtained in well irrigated field where increased dry weight (g) was observed with increasing phosphorus soil application methods.

Dry weight of leaf, ear and stem was higher with soil application than the seed application technique. The possible reason could be soil application phosphorous enabled the plants to absorb greater amount of the applied P resulting in more assimilate formation and partitioning to leaf, ear and stem. Arya and Singh (2001) found increased dry matter accumulation in maize with soil application methods. Maximum leaf and ear dry weight was noted in the fields that received P through foliar application was noted in the fields that received P at sowing time. Roman andWillium (1993) found that clay loam texture had maximum P fixation and to get proper amount of P availability, P-fertilizers should not be applied much before plantation to minimize P fixation through the application methods.

Table 7. Analysis of variance for dry weight as influenced by different phosphorus levels of maize.

SOV	DF	Dry weight of plant
Irrigation (I)	1	9087.0*
Phosphorus(P)	3	89791.0*
(I)*(P)	3	518.2*
Total	7	

Table 8. Effect of different phosphorus methods on dry weight (g) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	305.0d	152.67h
P1(Seed Application)	323.33c	182.68g
P2(Foliar Application)	421.0b	209.0f
P3(Soil Application)	481.67a	255.67e

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on Cobs diameter of maize crop

Results of analysis of variance showed significantly maximum cobs diameter with the application method of soil phosphorus at the rate in well irrigated conditions (table 9). With this application methods, water stress at vegetative and reproductive stages also reported better cobs diameter as compared to other phosphorus seed application method. Minimum cobs diameter was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus application method. Shortest cobs diameter was observed in water stress and well irrigated at vegetative and reproductive stage as compared to foliar and seed application methods. Better results were obtained in well irrigated field where increased cobs diameter was observed with increasing phosphorus application method of soil.

Table 9. Analysis of variance for Cobs diameter as influenced by different phosphorus levels of maize.

SOV	DF	Cob Diameter
Irrigation (I)	1	0.0417*
Phosphorus(P)	3	1.53500*
(I)*(P)	3	0.7917*
Total	7	

Table 10. Effect of different phosphorus methods on cobs diameter (g) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	5.1700c	5.1433c
P1(Seed Application)	6.2233c	6.01a
P2(Foliar Application)	6.9400b	6.16b
P3(Soil Application)	7.3900a	6.27b

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on number of grain rows per cob of maize crop

Results of analysis of variance showed significantly maximum No. of grains per row with the application methods of phosphorus at well and deficit irrigated conditions (table 11). With this application of seed and foliar method water stress at vegetative and reproductive stages also reported better No. of grains per row as compared to other phosphorus application methods. Minimum No. of grains per cobs was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus application method. No. of grains per row was observed in water stress at vegetative and reproductive stage followed by reproductive stages. Better results were obtained in well irrigated field where increased No. of grains per rows was observed with increasing phosphorus application methods of soil as compared to seed and foliar.

Number of grain rows per cob is also important component with respect to grain yield. Cob weight and number of grains per cob of maize crop can be determined by number of grain rows. Maximum grain rows per cob was observed in treatments, where was high application rate of phosphorus. Number of grain rows per cob were increased, ultimately effect on grain yield. It was due to maximum availability of phosphorus element. Another factor was well irrigation along with high phosphorus application method in soil. Minimum number of grain rows per cob were observed in treatments where of water deficient condition. Phosphorus application method in soil showed better results as compared to other methods of phosphorus application. Same findings were obtained by (Chakir, 2004).

Table 11. Analysis of variance for No. of grain per row as influenced by different phosphorus levels of maize.

SOV	DF	No. of grain per row
Irrigation (I)	1	18.375*

Phosphorus(P)	3	14.484*
(I)*(P)	3	37.931*
Total	7	

Table 12 Effect of different phosphorus No. of grains per row of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	25.4d	19.3g
P1(Seed Application)	31.34c	25.67f
P2(Foliar Application)	38.34b	31.0e
P3(Soil Application)	42.35a	38.9e

Figures sharing same letter did not differ significantly at ≤ 0.05.

Effect of different P application methods with full and half irrigation on number of grains per cob of maize crop

Results of analysis of variance showed significantly maximum No. of grains per cobs with the application methods of phosphorus at well and deficit irrigated conditions (table 13). With this application of seed and foliar method water stress at vegetative and reproductive stages also reported better No. of grains per cobs as compared to other phosphorus application methods. Minimum No. of grains per cobs was observed in well irrigated as well as in water stress at vegetative and reproductive stages without phosphorus application method. No. of grains per cobs was observed in water stress at vegetative and reproductive stage followed by reproductive stages. Better results were obtained in well irrigated field where increased No. of grains per cobs was observed with increasing phosphorus application methods of soil as compared to seed and foliar.

Number of grains is very important component of yield. Because more the number of grains, more will be the grain yield. Maximum number of grains were observed by applying phosphorus in soil, where frequent use of irrigation water was applied as compared to water deficient treatment. Soil application method of phosphorus showed better results as compared to other method of phosphorus application. The reason was that by applying phosphorus in soil, level of phosphorus was enhanced. There was maximum availability of phosphorus for maize crop. Soil method of phosphorus changed the chemical behavior of phosphorus, direct effect on number of grains and cob length. Same results were recorded by (Ahmad *et al*., 2011).

Table 13. Analysis of variance for No. of grain per cob as influenced by different phosphorus levels of maize.

SOV	DF	No. of grain rows per cob
Irrigation (I)	1	1.500*
Phosphorus(P)	3	42.94*
(I)*(P)	3	2.94*
Total	7	

Table 14 Effect of different phosphorus No. of grains per cobs of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	13.4d	9.33g
P1(Seed Application)	14.34c	10.67f
P2(Foliar Application)	15.34b	12.0e
P3(Soil Application)	17.35a	12.34e

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on 1000-grain weight of maize crop

The data related to number of grains per 100 gram and data of analysis shown in table 15. Mean comparison showed that with the application phosphorus methods showed significantly maximum number of grains spike in soil application method (320.30 g) whereas in control phosphorus lowest numbers of grains spike (201.90g) was obtained under well irrigated conditions. Phosphorus application method of foliar application also showed better results under water well irrigated conditions at vegetative and reproductive stages. It showed (320.0g, 294.53g and 218.37) grains spike under well water fields at vegetative + reproductive stages at soil, foliar and seed application methods, respectively. Control phosphorus application showed lowest number of grains spike under well and deficit irrigation stress as compared to other phosphorus application rate.

1000-grain weight is very important parameter regarding yield related attributes and have a potential in developing the grain yield. Thousand grain weight was maximum in treatments where high phosphorus was applied. Better results were obtained by application of phosphorus in soil in full irrigated treatments. It was observed that application of phosphorus in soil showed significant as compared to other methods of phosphorus application. Minimum 1000-grain weight was observed in control treatments where application rate of phosphorus was zero. So, high rate of phosphorus by applying in soil and frequent irrigation showed significant results as compared to water deficient treatments (Eltelib*et al*., 2006).

Table 15 Analysis of variance for 1000 grain weight as influenced by different phosphorus levels of maize.

SOV	DF	1000 grain weight
Irrigation (I)	1	61125.2*
Phosphorus(P)	3	10586.5**
(I)*(P)	3	1546.6**
Total	7	

Table 16. Effect of different phosphorus methods on 1000 grain (g) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	201.90d	124.13h
P1(Seed Application)	218.37b	148.40g
P2(Foliar Application)	294.53b	174.67f
P3(Soil Application)	320.30a	184.17e

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on Grain yield of maize crop

It was exposed that grain yield become increase with increasing phosphorus application methods (table 17). With the seed application (6.20 t ha^{-1}) phosphorus, maximum grain yield (8.41t ha^{-1}) was observed in well irrigated field conditions This application rate also showed better grain yield in water stress at vegetative + reproductive (6.54 t ha^{-1}) stages. Control phosphorus (P = 4.14tha^{-1}) reported lowest grain yield under well irrigated as well as in water stress. Better results were obtained in well irrigated field whereas water stress at vegetative stages and reproductive stages showed greater loss in grain yield through soil application methods.It was observed that grain yield increased significantly as irrigation and P soil application method applied. Reduction in number of tiller, number of grains spike^{-1} and 1000 grain weight due to water stress also causes the reduction in grain yield (Qadir*et al*., 1999; Usman, 2013). The reason could also be due to nutrient deficiency, low phosphorus solubility which caused reduction in biomass (Yu *et al*., 2013). Rathke*et al*. (2005) also reported lower yield without fertilizer application. Similar results were also reported by Kang *et al*. (2002), Zhang *et al*. (2008) and Jiang *et al*. (2012). Increased in grain and straw yields were observed due to increased irrigation levels by Reddi and Reddi (1995). Turk and Tawaha (2001) and Ahadiyat*et al*., (2014) also reported higher grain and straw yield with phosphorus application.

Table 17. Analysis of variance for grain yield as influenced by different phosphorus levels of maize.

SOV	DF	Grain Yield
Irrigation (I)	1	10.2835*
Phosphorus(P)	3	11.4935**
(I)*(P)	3	0.7809*
Total	7	

Table 18. Effect of different phosphorus methods on Grain Yield(t ha^{-1}) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	4.497e	4.147e
P1(Seed Application)	6.200cd	4.354e
P2(Foliar Application)	7.100b	5.944d
P3(Soil Application)	8.417a	6.544bc

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with half and full irrigation on biological Yield of maize

Biological yield in well and deficit irrigation application methods of P varies significantly , under well irrigated field conditions data showed that with the soil application methods of phosphorus at the slowed significantly maximum biological yield (9.39 t ha^{-1}) whereas in foliar application of phosphorus lowest biological yield (7.140 t ha^{-1}) was obtained. Under deficit irrigation at vegetative and reproductive stages, it also showed better results. Without phosphorus application, lowest grain yield under water stress was observed as compared to other phosphorus application methods. Water deficit drastically affects the grain yield both at vegetative and reproductive stages.

Data pertaining biological yield revealed that different methods of phosphorous had a non-significant effect on biological yield of maize. Highest biological yield was obtained in well irrigated with soil application methods at the rate of 100 kg ha^{-1} as compared to the control. Where the biological yield was lowest at the root growth of maize plants was greatest at 100 kg ha^{-1} P seed application method which resulted in best biological yield due to efficient photosynthesis and other physiological functions at the soil application methods. That's why the biological yield was the lowest in the control plots.

Table 19. Analysis of variance for biological yield as influenced by different phosphorus levels of maize.

SOV	DF	Biological Yield
Irrigation (I)	1	1.68540*
Phosphorus(P)	3	0.01505**
(I)*(P)	3	1.83752**
Total	7	

Table 20. Effect of different phosphorus methods biological yield (t ha^{-1}) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	5.5700d	5.1433e
P1(Seed Application)	6.1633c	6.4667c
P2(Foliar Application)	7.1400b	7.16b
P3(Soil Application)	9.3900a	7.27b

Figures sharing same letter did not differ significantly at ≤ 0.05

Effect of different P application methods with full and half irrigation on harvest index of maize crop

A different application method of phosphorus has a significant effect shown in (Table 21). Maize produced

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the highest harvest index of 25.56 kg ha^{-1} in the field which received the highest P at soil application methods and the lowest harvest index (21.82 kg ha^{-1}) when applied with the foliar application method. All the methods of P differed significantly from one another. In case of application methods, the highest harvest index (25.56 kg t ha^{-1}) was recorded in the well irrigated field application.

Harvest index in maize increased with increase due to P different application methods. The highest harvest index was recorded in the well and stressed irrigation fields that received the highest rate of P and the minimum harvest index was determined when P was applied at seed and soil application techniques. The increase in harvest index with higher application of soil might be due to the increase in yield and yield components of maize with higher P rates (Amanullah*et al.*, 2010b). Ibrikci*et al.*, (2005) found that P deficiency is invariably a common crop growth and yield-limiting factor, especially in soils high in calcium carbonate, which reduces P solubility. Harvest index increased when P was applied through the soil application technique than seed application of P. The decrease in harvest index with too late and too early P application might be due to the decrease in yield and yield components of maize as compared to higher yield and yield components when applied at sowing techniques of P.

Table 21. Analysis of variance for harvest index as influenced by different phosphorus levels of maize.

SOV	DF	Harvest Index
Irrigation (I)	1	104.542*
Phosphorus(P)	3	104.144**
(I)*(P)	3	8.290**
Total	7	

Table 22. Effect of different phosphorus methods Harvest Index (%) of maize under different irrigation regime.

Treatment	Well-watered	Water deficit
P0(control)	13.097e	12.377f
P1(Seed Application)	18.733c	13.097e
P2(Foliar Application)	21.827d	17.827d
P3(Soil Application)	25.560a	19.247c

Figures sharing same letter did not differ significantly at ≤ 0.05.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHORS CONTRIBUTIONS

All authors have equal contribution.

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