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Mitigating the effects of drought stress in wheat through potassium application

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Abstract
Wheat is a vital cereal crop that is cultivated under different climatic conditions and provides stable diet for millions of people in the world. To study the dual effect of drought stress and potassium levels in wheat a field experiment was conducted during winter 2015 at Agronomy Research Farm, University of Agriculture, Faisalabad, Pakistan. For this purpose, five drought regimes including No drought (D_1), drought at tillering (D_2), booting (D_3), flowering (D_4) and grain formation (D_5) stages and three potassium levels (60 : 90 : 120 kg ha^{-1}) were used. The experiment was laid out in randomized complete block design with split plot arrangement and repeated three times. Drought stress had drastic effect on yield and quality attributes when it occurred during critical growth stages in wheat crop, however, potassium application significantly improved the efficacy of these attributes by reducing the deleterious effects of drought. The maximum plant height (103 cm), number of productive tillers (291); number of spikelets per spike (18), number of grains per spike (52), 1000 grain weight (42.29), grain yield (5439 kg ha^{-1}), biological yield (9909 kg ha^{-1}), grain protein (12.90 %) and potassium content (0.714 %) were obtained through potassium application under normal as well as it was also improved performance of all these parameters under stress environment. According to conclusion the application of potassium sulphate in higher amounts effectively increased the efficiency of crop plants to cope with water shortage conditions and enhanced their abilities to execute well to give better yield.

Keywords: wheat, drought stress, potassium fertilizer, soil application, yield, protein content, potassium content

Introduction

In Pakistan the area under wheat cultivation is about 9180 thousand hectares and production is 25.979 million tons with an average of 2830 kg ha^{-1} during 2014-15 [15]. Wheat crop is the main source of carbohydrates and provides daily calories requirement. It contributes approximately 72% in diet and is an important crop sown all over the world [5]. Among the different stresses, drought is the most alarming one that effect agriculture and its production worldwide especially in arid and semi-arid regions. Reactive oxygen species produced during different physiological processes such as photosynthesis, photo-respiration, photo-oxidation and in-activation of hill energy under stress conditions. These reactive oxygen species affect the performance of plants and damage the cell that play role to mitigate the stress [9]. Under arid and semi-arid environment crop plants remained under stress conditions, but drought stress is the most alarming one that effects growth and development of crops and caused huge economic loss as result of complete failure of the crop under these situations [1, 29-31]. The degradation of soil resources occurred as result of imbalance use of fertilizer as well as nutrient mining due to high cropping intensity which caused reduction in yield up to 68 % and 64 % correspondingly, in wheat and rice [19]. Among different mineral nutrients, potassium plays an important role to control the adverse effect of drought. Application of potassium sulphate in solution as well as in fertilizer form enhanced biomass production and availability of some essential nutrients such as potassium, calcium, magnesium and phosphorus in saline soils. Potassium plays a vital role in increasing efficacy of photosynthesis, protein synthesis, enzyme activation, osmo-regulation, energy transfer, stomatal movement, cation-anion balance and stress resistance [17]. Potassium application in stress conditions helped to improve the peduncle length, number of grains per spike, biological yield and grain yield as compared to normal conditions [14].

Adequate amounts of potassium required by most of plants to tolerate drought stress and perform well to give optimum yield. It serves as a primary osmoticum to balance the turgor pressure of plants under stress environment. Potassium had an important role to mitigate the effects of drought stress by increasing nitrate reductase assimilation, K^+ ion accumulation, free proline, glycinebetaine and soluble protein [28]. In the presence of biotic and a-biotic stresses, it plays a vital role to mitigate them and also increases the abilities of plants to survive under stress environment. To adjust osmotic potential, sustain a higher turgor pressure and relative water content, crop needs an ample supply of K to enhance its capacity to stand under these conditions [27]. Adequate amount of potassium increased root penetration by making soil soft and porous. It enhanced ability of roots to absorb nutrient and water from large volume of soil. It increased resistance capacity of plants to cope with drought stress environment [11]. Potassium is a vital macronutrient that enhanced the capacity of plants to cope with different biotic and a-biotic environmental stresses. It also has positive affect to meet the current food requirement by improving crop yield and quality of produce under water shortage conditions [7]. Drought stress influenced accumulation of potassium in leaves. The mechanism of stomatal opening is greatly dependent on potassium concentration [22]. The application of macronutrients (Ca^{2+} and K^+) shows the positive role in mitigating the adverse effect of drought stress in the plant. Under drought, application of K^+/Ca^{2+} at higher rate increased the resistance in wheat varieties against these conditions [20]. Potassium played an important role in mitigating harmful effect of drought stress and acted as an indicator/ preventing agent to water stress conditions. Application of adequate amount of potassium fertilizer reduced negative effect of drought on grain yield of a crop [13]. Application of potassium fertilizer significantly enhanced plant root length and penetration to uptake water and absorb nutrients in large volume of soil. Potassium plays a vital role to tolerate the drought stress and helps plant to grow normally by maintaining their turgor pressure. In arid and semi-arid regions a farmer should need to estimate soil potassium supply and apply recommended dose to protect the environment [26]. Plant's dry matter accumulation, grain yield and uptake of N, P and K may be enhanced with an optimum amount of K nutrition. It may help in reducing the lethal effects of drought stress in wheat crop (8). Significance of K fertilization in improving wheat production under stress has been well known however, it is still unknown to determine exit quantities that should be applied under water shortage conditions. As we know that wheat is an irrigated crop and its productivity under water scarcity conditions at any developmental stage is frequently exposed to that environment. Similarly, high cost of potassium fertilizer raises a question about its feasibility under water shortage environment. The aim of this study was to investigate the dual effects of drought stress and potassium on growth, yield and quality of wheat, hence determine the potassium requirement to get optimum yield.

Materials and Methods

To study the role of potassium in mitigating the effects of drought stress in wheat under late sown conditions a field experiment was conducted during winter 2015 at Agronomy Research Farm, University of Agriculture, Faisalabad, Pakistan (31.43 ^{0}N, 73.08 ^{0}E at 184.4 meters above sea level). The physico-chemical analysis of experimental site were as soil texture was clay loam, ECe 2.4 d S m^{-1}, pH 7.8, SAR 1.79 (m mol L^{-1})$^{1/2}$, Organic matter 0.68%, Phosphorous 4.08ppm, Nitrogen 0.4ppm and test element (K) 245ppm. The experiment was carried out in randomized complete block design with split plot arrangement having net plot size of 5 m × 2.25 m with three replications.

Treatments

Factor A: Drought stress		Factor B: Potassium levels (kg ha^{-1})	
D_1	Control (No Drought)	K_1:	60
D_2	Drought at tillering stage	K_2:	90
D_3	Drought at booting stage	K_3:	120
D_4	Drought at flowering stage		
D_5	Drought at grain formation stage		

A wheat variety was sown as a test crop in the 1st week of December 2015 having 22.5 cm apart rows with single row hand drill. The recommended seed rate 125 kg ha^{-1} was used. The seed was treated with fungicide before sowing. Recommended rates of N: P applied @ 120: 90 kg ha^{-1} using urea and DAP as sources. Potassium applied as per treatment using potassium sulphate as source. Basic plant protection measures were adopted to keep crop free of weeds, insects and diseases. All the other agronomic practices were kept uniform and constant for all the treatments. During the course of study, data on following observation were recorded by following standard procedures. Plant height (cm), number of productive tillers (m^{-2}), number of spikelet's per spike, number of grains per spike, 1000-grain weight (g), grain yield (kg ha^{-1}), biological yield (kg ha^{-1}), grain protein content (%) and grain potassium content (%). The collected data were statistically analyzed by using Fisher's analysis of variance techniques and the difference between the treatments' means was compared by least significant difference (LSD) test at 5% probability level.

Results and Discussion

Yield and yield component

Plant height is a vital component that influenced total biomass production of a crop. Data regarding plant height presented in Table (1) showed that both the drought stress and potassium application has significant effect on plant height. The maximum plant height (103 cm) recorded in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while statistically lowest plant height (85 cm) given by the treatment D_2K_1 (drought at tillering stage and potassium applied @ 60 kg ha^{-1}). Under water shortage conditions the reduction in plant height may be due to decrease in water potential associated with cell turgidity, dehydration of protoplasm, higher respiration, reduction in cell division, cell expansion as well as reduction in inter-node elongation (16). The negative effect of drought stress is removed by increasing the supply of water to control transpiration through partial closure of stomata. Potassium significantly improved the plant height as it involved in regulation of various physiological and biological processes such as photosynthesis, respiration, enzyme activation, chlorophyll and creation of carbohydrate that significantly improved plant height under drought conditions. Results are in line with Aown *et al*. (2012) who reported that application of potassium in fertilizer form on various growth stages such as tillering/vegetative, flowering or grain formation stages significantly increased crop growth and development.

Data regarding the number of productive tillers m^{-2} presented in Table (1) revealed that both the drought stress and potassium application has interactive effect on it. The highest number of productive tillers (291) produced by the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha$_{-1}$) and minimum (227) measured in the treatment D_2K_1 (drought at tillering stage and potassium applied @ 60 kg ha^{-1}). Drought had drastic effect on vegetative capacity of crop, germination, emergence, decrease mean emergence time and number of plants per unit area when occurred during tillering and grain formation stage in cereals crop. It caused reduction in number of productive tillers by reducing plant population per unit area and increased the number of non-productive tillers per unit area (4). Potassium application in higher amount significantly improved the number of productive tillers by improving the crop stand establishment as well as increased number of leaves per plant by enhancing carbohydrate nutrition, photosynthesis; hormonal balance such as auxin, gibberellin and cytokianin that in general increased number of fertile tillers per unit area. These results are supported by Agashiry *et al*. (2014) who reported that K_2SO_4 significantly improved fertile tillers.

Number of spikelets per spike is a vital component of yield parameters that has a significant effect on grain yield of wheat. The results presented in Table (1) reflected that both the potassium application and drought stress has a significant effect on number of spikelets per spike. The maximum number of spikelets per spike [18] recorded in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while minimum (13.33) given by the treatment D_5K_1 (drought at grain formation stage and potassium applied @ 60 kg ha^{-1}). Water stress is the most alarming one that has adverse effect on number of fertile spikelets per spike by retarding photosynthesis activity, photo-period phenomenon and respiration as result of this spikelets produced wrinkled seeds when it occurs during grain formation stage in wheat [21]. Potassium effectively improved performance of various biochemical and physiological processes such as photosynthesis, respiration, enzyme activation, chlorophyll pigments of leaves and turgor pressure that played important role towards development of fertile spikelets per spike. These results are in confirmatory with El-Abady *et al*. (2009) who reported that foliar application of potassium improved number of spikelets per spike.

The production of any crop greatly depends on number of grains per spike that play a vital role towards economic yield of a crop. Data regarding number of grains per spike presented in Table (1) revealed that both the potassium application and drought stress has a significant effect on number of grains per spike. The highest number of grains per spike [52] were obtained in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while minimum [40] recorded in the treatment D_4K_1 (drought at flowering stage and potassium applied @ 60 kg ha^{-1}). Under water stress environment, number of grains per spike reduced as a result of less transformation of photo-assimilates to end product, number of leaves per plant, cell division, cell expansion as well as caused leaf senescence which has negative effect on photosynthesis when it occurred during flowering and post anthesis stages in wheat [24]. The soil application of potassium considerably removed the deleterious effects of drought stress at all growth stages in wheat by improving efficacy of yield and yield components. These results are in line with El-Abady *et al*. (2009) according to him spray of K_2O notably improved number of grains per spike.

1000-grain weight is a vital component of yield parameters that has great effect on crop production. Drought stress during different growth and development stages has negative effect on it. Data regarding 1000-grain weight presented in Table (1) concealed that both the potassium application and drought stress has a significant effect on it. The highest 1000-grain weight (42.29 g) recorded in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while statistically lowest (31.47 g) measured in the treatment D_5K_1 (drought at grain formation stage and potassium applied @ 60 kg ha^{-1}). Drought and heat stress conditions have negative effects on 1000-grain weight, number of spike m^{-2}, photosynthesis, number of days to heading and grain yield. Grain yield components particularly number of effective tillers per unit area, number of grains per spike, dry matter and harvest index was decreased up to 60%, 48% when drought stress occurred during seedling to maturity stage in wheat [18]. Potassium application in wheat considerably removed the deleterious effects of drought and improved the 1000-grain weight by increasing the efficiency of various physiological parameters such as cell division, cell growth, photosynthesis activity and increase length of grain filling period. It also improved water relations of plants, nutrients concentration and gas exchange, which improved biomass and efficiency of yield components. These results are in accordance with Rehman *et al*. (2014) who concluded that potassium application has significantly effect on 1000-grain weight.

Data presented in Table (1) showed that both the potassium application and drought stress has a significant effect on grain yield. The highest grain yield (5439 kg ha^{-1}) obtained in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while statistically (3330 kg ha^{-1}) measured in the treatment D_5K_1 (drought at grain formation stage and potassium applied @ 60 kg ha^{-1}) which is similar with treatment D_4K_1 (drought at flowering stage and potassium applied @ 60 kg ha^{-1}) and D_3K_1 (drought at flowering stage and potassium applied @ 60 kg ha^{-1}). Drought stress at post anthesis stage and grain formation stage caused reduction in grain yield by influencing the photo-assimilates production, power of sink to absorb photo-assimilates, rate and duration of grain filling period, efficiency number of effective tillers per unit area, number of grains per spike and 1000-grain weight [24]. The negative effect of drought could be decreased by increasing the availability of water to control transpiration through partial closure of stomata. Potassium application during flowering and grain formation stages effectively removed the deleterious effects of drought stress by improving the efficiency of various physiological and morphological processes such as photosynthesis, enzyme activation, energy balance, osmoregulation as well as performance of yield and yield component under stress environment. These results are in accordance with Aown *et al*. (2012) according to him K_2SO_4 effectively enhanced grain yield of wheat crop under water stress environment.

Biological activity is one of the vital attribute to measure the photosynthetic activity of a crop plant. The outcome related to biological yield is existed in Table (1) showed that both the potassium application and drought stress has positive effect on biological yield. The treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}) significantly produced highest biological yield (9909 kg ha-1) and statistically lowest biological yield (8742 kg ha^{-1}) measured in the treatment D_2K_1 (drought at tillering stage and potassium applied @ 60 kg ha^{-1}) which is similar with treatment D_4K_1 (drought at flowering stage and potassium applied @ 60 kg ha^{-1}) and D_5K_1 (drought at grain formation stage and potassium applied @ 60 kg ha^{-1}). Drought stress had drastic effects on photosynthesis, minerals availability, plant height, hormone growth and total dry weight as well as also influenced yield and yield components which has negative effects on final biological yield of a wheat crop (3). Due to more cell expansion, cell division, leaf surface area, nutrient absorption and photosynthetic activity biological yield of wheat crop is increased by application of potassium in higher amount under normal as well as stress environment. The results of present study are supported by Vafa *et al*. (2014) that foliar and soil application of potassium significantly improved biological yield.

Grain quality components

Data regarding grain protein contents concealed that both potassium application and drought stress have significant effect on it. The highest grain protein contents (12.90 %) obtained in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while lowest (9.40 %) recorded in the treatment D_5K_1 (drought at grain formation stage and potassium applied @ 60 kg ha^{-1}). Drought stress considerably influenced 1000-grain weight, grain yield, grain thickness, grain starch storage, concentration of others material in grain and protein to starch ratio that has a positive effect on grain protein content under stress situations [25]. The negative effects of drought stress could be reduced by increasing the availability of water to control transpiration through partial closure of stomata. Application of potassium significantly improved 1000-grain weight, availability of nutrients, grain starch content and improved the growth of protein producing enzymes under drought that ultimately increased the grain protein contents. These results are in line with Vafa *et al*. (2014) who reported that potassium application increased grain protein contents under stress environment.

Results presented in Table (1) revealed that both the drought stress and potassium application have significant effect on grain potassium content. The higher grain potassium content (0.714 %) recorded in the treatment D_1K_3 (no drought and potassium applied @ 120 kg ha^{-1}), while statistically lowest grain potassium content (0.403 %) given by the treatment D_2K_1 (drought at tillering stage and potassium applied @ 60 kg ha^{-1}) which is similar with treatment D_4K_1 (drought at flowering stage and potassium applied @ 60 kg ha^{-1}). Drought stress has negative effect on photosynthesis, hormone balance, respiration and plant mineral nutrition by inhibiting root ability to absorb nutrient efficiently as well as also influenced transportation of nutrients and photo-assimilates from one part to another in plants that has deleterious effect on grain potassium content [22]. Potassium played an important role to maintain turgor pressure and osmotic adjustment that could be helpful to sustain lower leaf water potential and increased ability of plants to cope with drought stress conditions. As the concentration of potassium nutrition increased, grain potassium contents improved as result of increase in absorption through roots under stress environment. These results are conformities by Chachar *et al*. (2016) that potassium enhanced grain potassium content under stress conditions.

Table 1: Mitigating the effects of drought stress on yield and yield components in wheat through potassium application.

Treatments	Plant Height (cm)	No. of productive tillers (m^{-2})	No. of spikelet's per spike	No. grains per spike	1000 grain weight (g)	Grain Yield (kgha^{-1})	Biological Yield (kgha^{-1})	Grain potassium content (%)	Grain protein content (%)
D_1K_1	95bc	261d	16.33bc	48c	40.18c	4530c	9715c	0.588f	10.10gh
D_1K_2	97b	283b	17b	50b	41.30b	4965b	9754b	0.685b	11.98de
D_1K_3	103a	291a	18a	52a	42.29a	5439a	9909a	0.714a	12.90a
D_2K_1	85k	227l	13.66hi	40hi	37.71f	3424i	8742j	0.403l	10.00h
D_2K_2	87ijk	230kl	14.66efg	42fg	38.46e	3764f	9118g	0.535h	10.25gh
D_2K_3	89fghi	239hi	15def	44de	39.06d	4090d	9562d	0.654c	12.15cde
D_3K_1	88hijk	233jk	14.33fgh	41gh	35.31i	3330j	8674k	0.478j	9.45i
D_3K_2	90fgh	237ij	14.66efg	43ef	36.43h	3667g	9045h	0.520hi	10.5g
D_3K_3	91ef	245fg	15.33de	45d	37.35g	4083d	9516d	0.622d	12.30bcd
D_4K_1	86jk	239hi	14.33fgh	40j	32.55m	3359j	8776j	0.404l	9.50i
D_4K_2	88ghij	242ghi	14.66efg	41hi	33.87k	3603h	9127g	0.471j	11.50f
D_4K_3	91efg	248ef	15.66cd	42gh	34.64j	3831e	9367f	0.557g	12.50abc
D_5K_1	92de	243fgh	13.33i	41ij	31.47n	3363j	8521l	0.421k	9.40i
D_5K_2	93cde	252e	14ghi	42fg	32.56m	3692g	8887i	0.505i	11.75ef
D_5K_3	94cd	261c	15.33de	43ef	33.42l	4082d	9438e	0.604e	12.65ab

Means followed by same letter within the column do not differ significantly at 5% probability level. K_1 = 60 Kg ha^{-1}, K_2 = 90 Kg ha^{-1}, K_3 = 120 Kg ha^{-1}, D_1 = Control (no drought); D_2 = Drought at tillering stage; D_3 = Drought at booting stage; D_4 = Drought at flowering stage; D_5 = Drought at grain formation stage

Economic Analysis

Economic analysis revealed that maximum benefit cost ratio (1.59) and net income (54872 Rs. ha^{-1}) was recorded in treatment D_1K_3 where four irrigation at all critical growth stages (no drought) and potassium applied @ of 120 kg ha^{-1} (Table 2).

Table 2: Mitigating the effects of drought stress on net income and benefit cost ratio in wheat through potassium application.

Treatment	Gross Income (Rs. ha^{-1})	Total expenses (Rs. ha^{-1})	Net income (Rs. ha^{-1})	Benefit-cost ratio (BCR)
D_1K_1	124539	86447	38092	1.44
D_1K_2	134482	89535	44947	1.50
D_1K_3	147494	92622	54872	1.59
D_2K_1	99025	85447	13578	1.16
D_2K_2	106722	88535	18187	1.21
D_2K_3	114431	91622	22809	1.25
D_3K_1	97074	85447	11627	1.14
D_3K_2	104650	88535	16115	1.18
D_3K_3	114125	91622	22503	1.25
D_4K_1	98035	85447	12588	1.15
D_4K_2	103899	88535	15364	1.17
D_4K_3	108974	91622	17352	1.19
D_5K_1	96921	85447	11474	1.13
D_5K_2	104477	88535	15942	1.18
D_5K_3	113752	91622	22130	1.24

K_1 = 60 Kg ha^{-1}, K_2 = 90 Kg ha^{-1}, K_3 = 120 Kg ha^{-1}, D_1 = Control (no drought); D_2 = Drought at tillering stage; D_3 = Drought at booting stage; D_4 = Drought at flowering stage; D_5 = Drought at grain formation stage

Conclusion

It was concluded that application of potassium sulphate in higher amount as compare to recommend dose effectively improved performance of yield and yield components under drought stress conditions by removing negative effects of water stress. So, it was recommended that soil application of K_2SO_4 @ 120 Kg ha^{-1} enhanced the crop productivity as well as gave maximum net returns under stress conditions.

References

1. Abbas Z, Ahmad I, Shakeel A, Abdullah M, Islam M, Muhammad S, Murtaza G, Ahmad M. Effect of phosphorous fertilizer and water stress on protein and phenolic contents in cotton (*Gossypium hirsutum* L.). Pak. J. Agric. Res. 2015; 28(4):363-368.
2. Agashiry SA, Kordlaghari KP, Pouzesh H, Rahimi A. Effects of super-absorbent and different levels of potassium sulphate on soil moisture and morphological features of rain-fed wheat in Boyer Ahmad Region, Iran. Ann. Biol. Res. 2014; 3(6):2781-2784.
3. Aghanejad M, Mahfoozi S, Sharghi Y. Effects of late-season drought stress on some physiological traits, yield and yield components of wheat genotypes. Biol. Forum an Int. J. 2015; 7(1):1426-1431.
4. Akram HM, Ali A, Sattar A, Rehman HSU, Bibi A. Impact of water deficit stress on various physiological and agronomic traits of three basmati rice (*Oryza sativa* L.) cultivars. J. Anim. Plant Sci. 2013; 23(5):1415-1423.
5. Ali A, Ali N, Ullah N, Ullah F, Adnan M, Swati ZA. Effect of drought stress on the physiology and yield of the Pakistani wheat germplasms. Int. J. Adv. Res. Tech. 2013; 2(7):419-430.
6. Aown M, Raza S, Saleem MF, Anjum SA, Khaliq T, Wahid MA. Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticum aestivum* L.). J. Anim. Plant Sci. 2012; 22(2):431-437.
7. Aslam M, Zamir MSI, Afzal I, Amin M. Role of potassium in physiological functions of spring maize (*Zea mays* L.) grown under drought stress. J. Anim. Plant Sci. 2014; 24(5):1452-1465.
8. Baque A, Karim A, Hamid Tetsushi H. Effect of fertilizer potassium on growth, yield and nutrient uptake of wheat (*Triticum aestivum* L.) under water stress condition. S. Pac. Stud. 2006; 27(1):26-35.
9. Boutraa T, Akhkha A, Al- Shoaibi AA, Alhejeli AM. Effect of water stress on growth and water use efficiency (WUE) of some wheat cultivars (*Triticum durum*) grown in Saudi Arabia. J. T. Uni. Sci. 2010; 3:39-48.
10. Chachar MH, Chachar NA, Chachar Q, Mujtaba SM, Chachar S, Chachar Z. Physiological characterization of six wheat genotypes for drought tolerance. Intr. J. Res. Granthaalayah. 2016; 4(2):184-196.
11. Ebrahimi M, Roozbahani A, Baghi M. Effect of potash fertilizer and amino acids on yield components and yield of maize (*Zea mays* L.). Crop Res. 2014; 48(1)2 &3):15-21.
12. El-Abady MI, Seadh SE, El-Ward A, Ibrahim A, El-Emam AAM. Irrigation withholding and potassium foliar application effects on wheat yield and quality. Int. J. Sustain. Crop Prod. 2009; 4(4):33-39.
13. Fooladivanda Z, Hassanzadehdelouei M, Zarifinia N. Effects of water stress and potassium on quantity traits of two varieties of mung bean (*Vigna radiate* L.). Cercetari Agronomice in Moldova. 2014; 47(1):107-114.
14. Ghaznavi AF, Abdolshahi R. Study on effect of potassium sulfate application on drought tolerance of bread wheat (*Triticum aestivum* L.). 2011. Plant Ecophysiol. 2011; 3:87-93.
15. Govt. of Pakistan. Pakistan Economic Survey. Ministry of finance, Islamabad. 2015; 2: 7-28.
16. Hammad SAR, Ali OAM. Physiological and biochemical studies on drought tolerance of wheat plants by application of amino acids and yeast extract. Ann. Agric. Sci. 2014; 59(1):133-145.
17. Kausar A, Gull M. Effect of potassium sulphate on the growth and uptake of nutrients in wheat (*Triticum aestivum* L.) under salt stressed conditions. J. Agric. Sci. 2014; 6(8):101-112.
18. Kilic H, Yagbasanlar T. The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum ssp. durum*) cultivars. Not. Bot. Hort. Agrobot. Cluj. 2010; 38(1):164-170.
19. Mahmood IA, Arshad A, Shahzad A, Asif M, *et al*. Crop residues and phosphorus effect on yield and economics of direct seeded rice and wheat grown under saline-sodic soil. Pak. J. Agric. Res. 2016; 29(1):25-34.
20. Majid SA, Asghar R, Murtaza G. Potassium-calcium interrelationship linked to drought tolerance in wheat (*Triticum aestivum* L.). Pak. J. Bot. 2007; 39(5):1609-1621.
21. Mohammadi MM, Maleki A, Siaddat SA, Beigzade M. The effect of zinc and potassium on the quality yield of wheat under drought stress conditions. Intr. J. Agric. Crop Sci. 2013; 6(16):1164-1170.
22. Pranckietiene I, Miskine EM, Pranckietis V, Dromantiene R, Sidlauskas R, Vaisvalavicius R. The effect of amino acids on nitrogen, phosphorus and potassium changes in spring barley under the conditions of water deficit. Zemdirbyste-Agric. 2015; 102(3):265-272.
23. Rahman MA, Rahman MM, Hasan MM, Begum F, Sarker MAZ. Effects of foliar application of potassium orthophosphate on grain yield and kernel quality of wheat. (*Triticum aestivum* L.) under terminal heat stress. J. Agric. Res. 2014; 39(1):67-77.
24. Saeidi M, Abdoli M. Effect of drought stress during grain filling on yield and its components, gas exchange variables, and some physiological traits of wheat cultivars. J. Agric. Sci. Tech. 2015; 17:885-898.
25. Vafa P, Naseri R, Moradi M. The effect of drought stress on grain yield, yield components and protein content of durum wheat cultivars in Ilam Province, Iran. Intr. J. Biol. Biomol. Agric. Food Biotech. Eng. 2014; 8(6):631-636.
26. Valadabadi SA, Farahani HA. Studying the interactive effect of potassium application and individual field crops on root penetration under drought condition. J. Agric. Biotech. Sustain. Dev. 2010; 2(5):82-86.
27. Wang M, Zheng Q, Shen Q, Guo S. The critical role of potassium in plant stress response. Int. J. Mol. Sci. 2013; 14:7371-7390.

28. Zhang L, Gao M, Li S, Alva AK, Ashraf M. Potassium fertilization mitigates the adverse effects of drought on selected *Zea mays* cultivars. Turk. J. Bot. 2014; 38:713-723.
29. Ali Q, Ahsan M, Ali F, Aslam M, Khan NH, Munzoor M, Mustafa HSB. Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. -Advancements in Life sciences. 2013; 1(1):52-63.
30. Ali Q, Ahsan M, Malook S, Kanwal N, Ali F, Ali A, Ahmed W, Ishfaq M. Screening for drought tolerance: comparison of maize hybrids under water deficit condition. -Advancements in Life Sciences. 2016; 3(2):51-58.
31. Ali Q, Ali A, Ahsan M, Ali S, Khan NH, Muhammad S. Line × Tester analysis for morpho-physiological traits of *Zea mays* L. seedlings. -Advancements in Life Sciences. 2014; 1(4):242-253.