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RESEARCH ARTICLE

Soil applied potassium enhanced the oil contents in hybrid mustard crop under water deficit condition

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ABSTRACT

Mustard is an important oil seed crop and plays vital role in boosting the country economy especially in Pakistan. Unfortunately, under the sudden fluctuation in the climatic conditions, water stress is one of the most drastic factors restricting its production. To mitigate the water scarcity impact, soil applied potash has emerged as a sustainable approach in improving the crop oil production. For this purpose, two years filed trials were conducted at the Agronomic field research-area, Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan during two consecutive growing seasons 2017-18 and 2018-19. The Randomized Complete Block Design was used with two factorial arrangements having three replications. Different factors were Fa; irrigation water stress i.e. (no stress (control)), stress at vegetative stage (S_{veg}), stress at vegetative & reproductive stages ($S_{veg+rep}$)) and Fb; potash application i.e. (0, 30, 60 and 90 kg ha^{-1}) at the time of sowing. Mustard hybrid (45S42) was used as a test specie. Observations shown that water stress at S_{veg} resulted in grain yield reduction (47%) as compared to control. In the case of potash fertilizer treatments particularly at 60 kg ha^{-1} was significantly alleviated the detrimental effect (15% in yield-related components) of water stress both in S_{veg} and $S_{veg+rep}$ conditions as per control. Nevertheless, potash application at 60 kg ha^{-1} depicted increase of oil-contents (35%) as per with other treatments under the applied irrigation water stress at S_{veg} and $S_{veg+rep}$ conditions during the both years of trials. Based on the results of economic analysis, potash application at 60 kg ha^{-1} is an easy, efficient, commercially feasible and cost-effective agronomic approach for compensating the adverse effects of water stress in mustard crop.

Keywords: Hybrid mustard; Irrigation water stress; Oil contents; Potash

INTRODUCTION

The water is considered to be one of the most significant inputs required for agricultural production. Plants/crops require it throughout their life cycle to achieve good results (Nawaz et al., 2021). Its deficiency and excess affected the various processes in plants and delayed the growth and development of crops. In this case, water scarcity is a major problem in the world (Reddy and Vivekanandan, 2004). All international forecasts indicate that climate change is severe and that its criticality should increase in the future. As a result of climate change, water shortages and surpluses are believed to be the main challenges for sustainable agricultural production. A condition that leads to water scarcity, known as drought, is the main limiting factor for the growth and yield of agricultural production affecting 40-60% of the world's agricultural land (Nawaz et al., 2020). Today's growing demand for food has been increased by an ever-growing population leading to shrinkage of world's water resources. Pakistan is a country hard hit by the Climate Change Vulnerability Index and is at high risk from frequent droughts and floods (Saleem et al., 2007). Furthermore, industrialization and urbanization will lead to increased water scarcity in the coming years. In conditions of water scarcity, plant processes such as enzymatic and hormonal activities, respiration, photosynthesis, absorption and translocation of ions and nutrients are altered that affect the growth and development of plants. Drought stress occurs when water losses from plants through evaporation and transpiration exceed the availability of water to plants from the soil and the atmosphere (Fereres and Soriano, 2007).

To compete with prevailing climate change, adoption is required. Adoption is one of the best strategies for responding to the effects of climate change (Ahmad et al., 2011). Oilseed crops such as mustard, and canola are well accepted in areas with less water (Amanullah et al., 2011). As the world's population continues to expand, there is a growing demand for oil-rich products and crops for human

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and animal consumption. Edible oilseeds are one of the staple foods in the human diet after harvesting grains and sugar crops (Anjum et al., 2005). This vegetable oil ingredient is the most important source for the human body which requires essential fatty acids and vitamins E and D. Now-a-days, mustard crop is well-known to be a good source having vegetable oil > 45% and protein >43.6% contents in the world after soybeans and palm crop. It has ability to grow in a variety of soil types and show tolerant behavior against abiotic stresses but less susceptible to biotic stresses including's insects, pests, and disease (Brandt, 1992). When plants induced with environmental stresses, the adaptations mechanism is adopted in its own way through durability and productivity to resist or avoid the impacted stresses.

To withstand various stressful conditions, plants developed a wide range of mechanisms during the process of evolution (Mandal and Sinha, 2004). In order to improve the resistance of plants to various environmental stresses, many research trials have been reported the crucial role of mineral nutrients in estimating a 60% reduction in growth of agricultural land due to nutrient deficiencies. Therefore, crop productivity can be greatly increased by increasing the availability of mineral nutrients for plants grown under limited conditions (Cakmak, 2002). Among the mineral nutrients, the role of potash in plant survival and perseverance under environmental stress is very important. Under the conditions of water shortage, it means that the stomata will close, partially or completely, depending on the availability of water from the mesophyll. Therefore, it regulates the breathable water. In this way, it reduces water loss during periods of drought. Potash is also essential for absorbing water through the root system in conditions of soil moisture deficiency (Umar, 2006).

Thus, the current study was planned to find out the optimum water requirements for hybrid mustard crop and the role of potassium to mitigate water deficient conditions.

MATERIALS AND METHODS

Experimental site and description

Research trial was conducted during two consecutive growing seasons 2017-18 & 2018-19 in the experimental site of the Department of Agronomy, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan (30.2°N, 71.43°E; 122 m AMSL). Multan is the city of southern Punjab, Pakistan. Climate of the area has features of arid nature having hot summers and cold winters. Trial was planted during 2nd fortnight of October and harvested during 1st fortnight of March during both the years of trials. Weather data for the growing seasons of mustard crop during the both the years of study is given in the Fig 1. Weather during 2nd year of study was less harsh having relatively less temperature and more rainfall intensity, but rains occur during lateral stage of the crop, which caused delay in harvesting and has non-significant effect on the crop growth and developmental conditions. The soil of the experimental area was silt loam (EC 2.7 dSm^{-1}, pH 8.18, Organic matter content 0.8% as per classification criteria of United States Department of Agriculture (USDA) using texture triangle (Nawaz et al., 2019).

Crop husbandry

Randomized complete block design (RCBD) with two factorial arrangements were replicated thrice including's factors, Fa; irrigation water stress i.e. (no stress (control)), stress at vegetative stage (S_{veg}), stress at vegetative & reproductive stages ($S_{veg+rep}$)) and Fb; potash application i.e. (0, 30, 60 and 90 kg ha^{-1}) at the time of sowing. Mustard hybrid (45S42) was used as a test specie. A piece of land was selected for experiment and levelled properly to ensure balanced water distribution throughout the field. Pre-soaking irrigation was applied. Few days later, when observed optimum soil moisture contents as a best wattar condition (soil water holding capacity), seed bed was prepared. To prepare fine seed bed, soil was cultivated with tractor mounted cultivator followed by planking. Fertilizer was uniformly applied by broadcasting before last cultivation. Fertilizer rate for Phosphorous at 60 kg ha^{-1}. Nitrogen was applied at the rate of 90 kg ha^{-1}. Diammonium Phosphate (DAP) was used to fulfill Phosphorous needs of the plants. Sulphate of Potash (SOP) was used as a Potash source for plants. Urea was used to supply nitrogen to plants. All phosphorous and half urea (nitrogen) were broadcasted as basal dose Remaining amount of urea (nitrogen) was applied at flowering stage. Potash was applied as a basal dose according to treatments.

Hybrid mustard cultivar was planted in rows with the help of hand-drill keeping row to row distance of 45cm. To keep uniform plant population, thinning was done after emergence. Irrigation was applied as per treatments. Weeding and plant protection measures were done as per need to keep field free from weeds, insects and diseases.

OBSERVATIONS

Potash content of the plants

The potash contents of the plants were recorded using flame photometer followed by protocol described by Ryan et al. (2001). For potash analysis, 5 plants along with grains were selected, weighted, dried and crushed into fine powder. A diluent was prepared to dilute this powder/ ash for potash determination. To prepare this diluent,

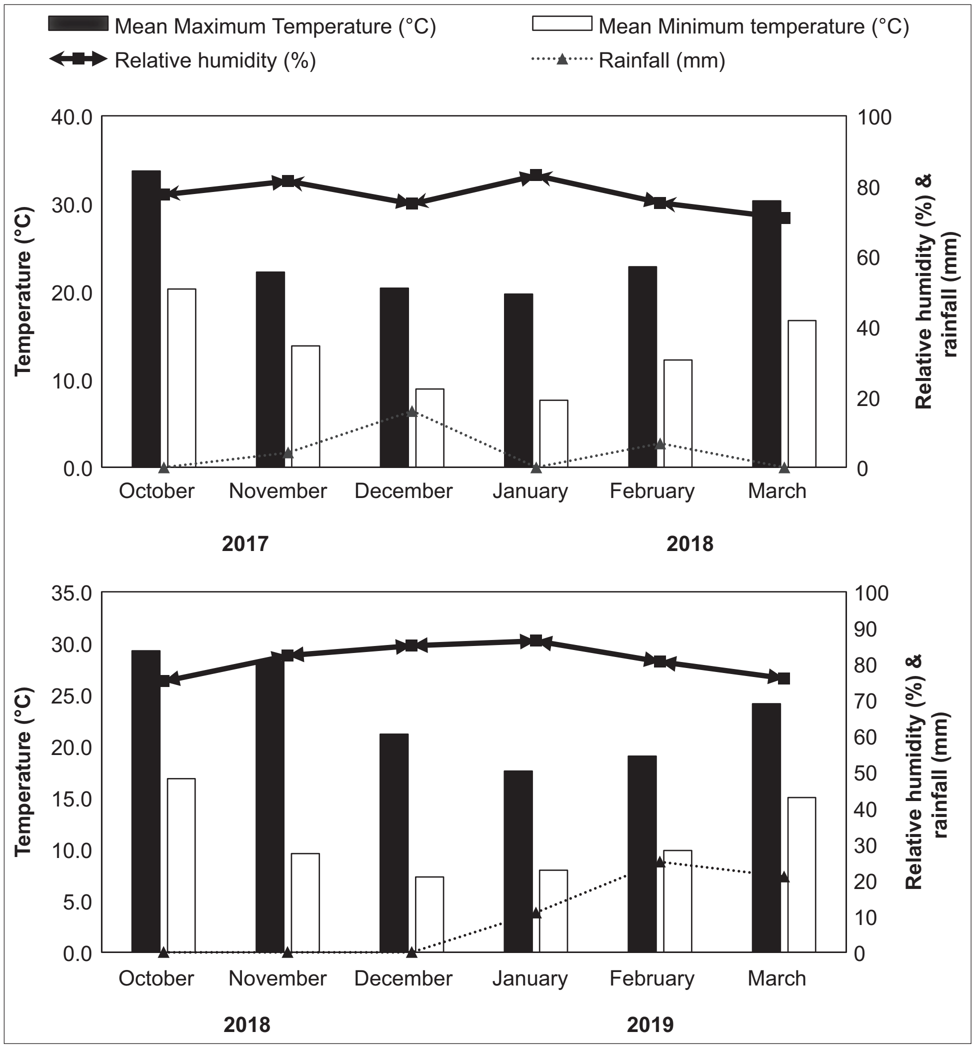

Fig 1. Meteorological data for growing period of mustard crop during the year 2017-18 and 2018-19

hydrochloric acid (10%) and deionized water (90%) were used. 1 g of fine powdered of each sample was taken into platinum crucible, moisten with 5 drops of deionized water, 5 drops of sulphuric acid and 5ml of hydrofluoric acid (40%). Sample was placed on hotplate for drying. During this process, repeated the addition of diluents and continue to evaporate until complete decomposition of the tested sample. Extracted the residue and transfer the solution quantitatively to a 200 ml volumetric flask. Added the diluent to dilute the solution. Flame photometer was set up as per instruction for potash element. Articulated the diluent solution and reading was set to zero. Standards of 2, 4, 6 & 10 ppm were enunciated into the flame photometer. A standard curve of potash concentration versus intensity was plotted. Enunciated the sample solution into the flame and the reading was recorded which fall within the range of the calibration curve. The percentage of potassium in the sample was determined using the results of calibration curve. Following formula was used to calculate potash % in the tested sample;

Potash % = K sample (ppm) x 200 x 100/1000000 x sample weight (g)

Yield and oil content traits

In order to record yield related traits like number of branches/plant, number of seeds/pod, 1000 seed weight, plant height and pod fertility, a sample of ten representative plants from each treatment were chosen at the time of crop physiological maturity. In order to obtain seed/grain yield per plot, remaining plants were manually harvested, dried to appropriate level. Then, threshing was done manually. This yield data per plot was then converted to calculate per hectare yield.

The oil content (%) of the samples were assessed using solvent extraction technique which is considered as most efficient and safer technique. In this technique, weighted seed samples were grinded first and converted into seed cake. This seed cake was then purged with distillate (hexane) which releases oil. Extracted oil and solvent were then

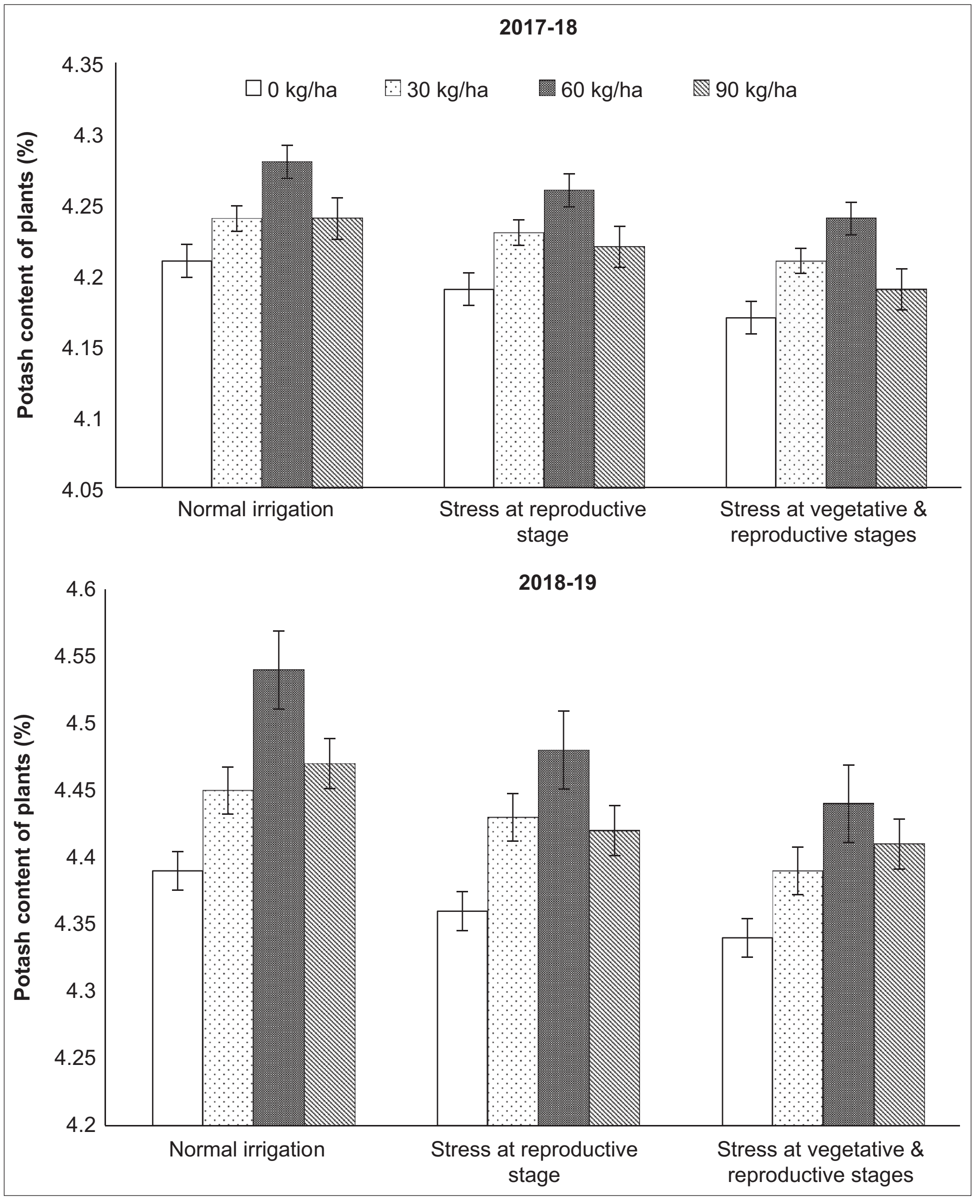

Fig 2. Effect of different levels of potash fertilizer on potash content of the plants

heated to 100 ºC in a sealed chamber. This heating results in distillation of solvent. Obtained oil was then weighted to calculate oil content of the sample. This procedure was repeated for each treatment. Oil samples were used to determine potash content in oil using flame atomic absorption spectrometry (FAAS).

Benefit cost ratio (BCR) analysis

Cost benefit ratio is an important analysis which indicates economic feasibility and effectiveness of tested treatments. Thus, economic analysis was done by calculating total expenses right from sowing to harvesting of various treatments. These expenditures include cost of soil preparation, planting, applied fertilizers, irrigations, experimental land rent, plant protection measures, harvesting and threshing. To calculate gross income, current mustard produce and straw price was used. Benefit cost ratio was calculated by following the given formula;

Benefit cost ratio = Gross income/total expenses

Statistical analysis

For data analysis, ANOVA (analysis of variance) was used by following RCBD (randomized complete block design) two-way factorial arrangements (Steel et al., 1997). Statistix, v8.1 software was used for precise and advanced statistical analysis. LSD (Least significant difference) of 5% probability ($P \leq 0.05$) was used for data analysis. Results obtain from data analysis were used for comparison of differences between treatments.

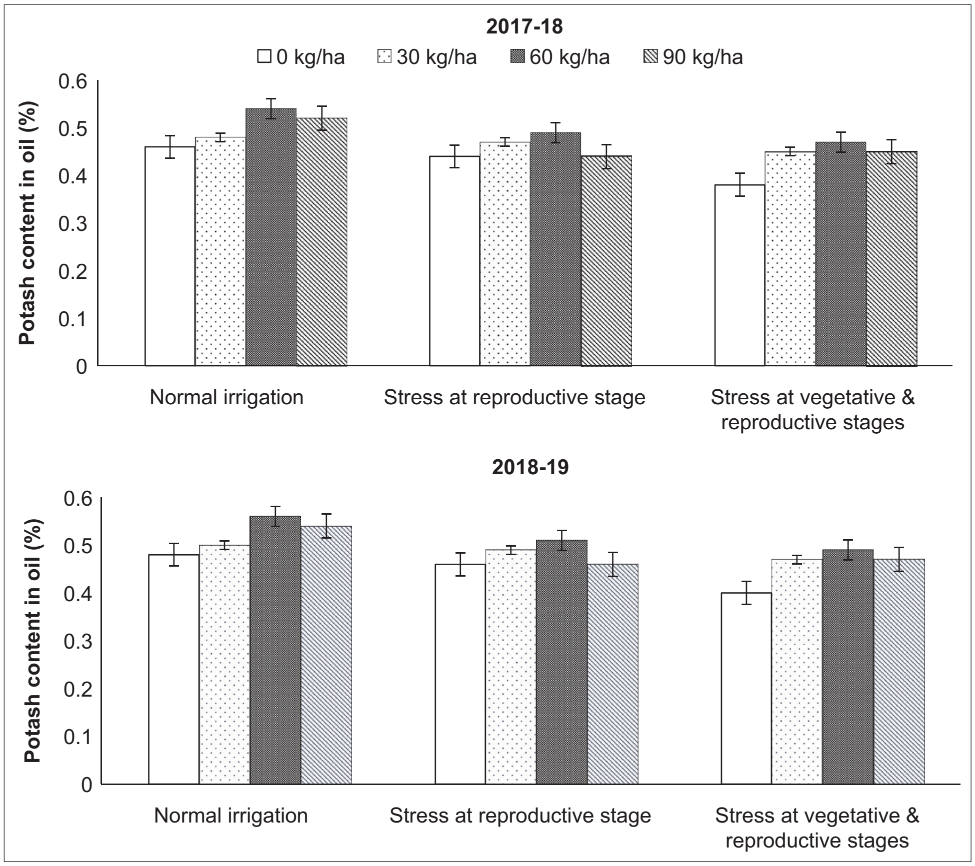

Fig 3. Effect of different levels of potash fertilizer on potash content in oil

Microsoft excel program was used for data entry and graphical representation.

RESULTS

Morphological and agronomic traits

Prominent reduction in morphological and agronomic traits were observed in mustard crop grown under water stress conditions. However, significant impact of potash application was observed regarding agronomic traits in plants both under normal and water stress conditions. During both years of study, potash application increased plant height, number of branches/plants, and number of seeds/pods under normal as well as water deficient conditions (Table 1).

Yield traits

Different irrigation and potash levels have significant impact on yield and yield related traits like pod fertility, 1000 seed weight and seed weight per plot. Significant difference in 1000-grain weight was recorded at various irrigation levels. Control irrigation resulted in highest 1000-grain weight, while it was lesser under water stressed conditions. However, impact of various potash levels on 1000-grain weight was not significant. Irrigation levels affected seed/grain yield significantly. Control irrigation produced highest grain yield while it was lowest under severe water stress condition ($S_{veg+rep}$). Seed yield was also impacted significantly under various potash levels. (Table 2).

Seed oil content

Oil content % of the seed differ significantly under various irrigation and potash levels. Maximum oil content percentage was present in mustard crop grown under three irrigation system (control). Similarly, oil content percentage (55.11%) of 60 kg ha^{-1} potash was significantly higher in comparison with control. Thus, both potash and irrigation levels induced oil content percentage when applied under normal levels. Oil yield has also positive co-relation with irrigation levels. Potash level@60 kg/ha has significant positive impact on oil yield. (Table 2).

Benefit cost ratio (BCR)

Two years economic analysis revealed that drought stress caused a significant decrease in benefit cost ratio (BCR). Under water stress condition, potash application enhanced economic benefits. Thus, potash application is found to be a good mitigating technique under water stress ensuring good profitability as well as benefit cost ratio to the farmers (Table 3).

Table 1: Effect of potash on morphological parameters of hybrid mustard under water deficit conditions

Potash (kg ha^{-1})	2017-18				2018-19			
	Irrigation water stress							
	Normal	S $_{(Rep)}$	S $_{(Veg+Rep)}$	Mean	Normal	S $_{(Rep)}$	S $_{(Veg+Rep)}$	Mean
Plant height (cm)								
0	174.00 f	165.00 i	152.67 l	163.89 D	154.83 l	167.00 i	176.00 f	165.94 D
30	181.00 c	170.00 h	154.00 k	167.67 C	156.00 k	172.00 h	181.00 e	169.67 C
60	184.00 b	173.00 g	160.00 j	183.56 A	182.00 d	183.00 c	191.50 a	185.50 A
90	189.67 a	179.00 e	180.00 d	172.33 B	162.00 j	175.00 g	186.00 b	174.33 B
Mean	181.67 A	172.25 B	161.67 C		163.71 C	174.25 B	183.62 A	
Number of branches plant^{-1}								
0	6.00 e	5.00 f	2.00 i	4.33 D	6.00 e	5.00 f	2.00 i	4.33 D
30	7.00 d	6.17 e	3.00 h	5.39 C	7.00 d	6.17 e	3.00 h	5.39 C
60	9.50 b	10.50 a	5.00 f	8.33 A	9.50 b	10.50 a	5.00 f	8.33 A
90	8.00 c	8.17 c	4.00 g	6.72 B	8.00 c	8.17 c	4.00 g	6.72 B
Mean	7.62 A	7.46 B	3.50 C		7.62 A	7.46 B	3.50 C	
Number of pods plant^{-1}								
0	166.33 l	178.00 i	187.00 f	177.11 D	183.00 f	174.00 i	162.17 l	173.06 D
30	167.00 k	183.00 h	192.00 e	180.67 C	188.00 e	179.00 h	163.00 k	176.67 C
60	193.00 d	194.00 c	203.33 a	196.78 A	198.83 a	190.00 c	189.00 d	192.61 A
90	173.50 j	186.00 g	197.00 b	185.50 B	193.00 b	182.00 g	169.50 j	181.50 B
Mean	174.96 C	185.25 B	194.83 A		190.71 A	181.25 B	170.92 C	
Number of seeds pod^{-1}								
0	7.00 d	5.00 f	3.50 g	5.17 D	7.00 d	5.00 f	3.50 g	5.17 D
30	8.00 c	7.00 d	5.00 f	6.67 C	8.00 c	7.00 d	5.00 f	6.67 C
60	10.17 a	9.00 b	8.00 c	9.06 A	10.17 a	9.00 b	8.00 c	9.06 A
90	9.00 b	8.00 c	6.00 e	7.67 B	9.00 b	8.00 c	6.00 e	7.67 B
Mean	8.54 A	7.25 B	5.62 C		8.54 A	7.25 B	5.62 C	

Mean values sharing different letters are statistically significant at *p*@ 0.05

DISCUSSION

The requirement of water during the physiological processes is the most critical factor in providing the main source for nutrients movement and metabolic activities in the mustard crop (Din et al., 2011: Dayal et al., 1995). Ultimately, plants showed significantly slow growth and development under water stress condition. The reduction in the crop yield depends on its intensity and duration of water stress which observed ±60% yield in mustard crop in the rain-fed climatic condition (Chauhan et al., 2007; Ahmad et al., 2018). It has been observed that the least yield reduction in the mustard crop was noted during the water stress applied at the reproductive growth stages (Ahmadi and Bahrani, 2009). Response of plants towards water deficient conditions determines plants sensitivity andsurvival. In order to alleviate the adverse impacts of various abiotic stresses, several approaches have been used in various crops. Various studies has been proved that applied potash as a nutrient in the soil or foliar improved the resistance in the plants against environmental stresses especially water stress conditions (Ali et al., 2003).

The treatment applied potash nutrients fertilizer ameliorated harmful effects of drought in the plants by enhancing the various physiological and growth processes (Ahmad et al., 2011). Which showed the significant increase in seed and oil contents in mustard crop even under the adverse water stress condition at flowering and pod development stages (Sangakkara et al., 2001). No doubt, water stress affected the mustard crop at both the stages (vegetative and reproductive) but the trend in the projected study under potash applied plants might be due to decrease in the transpiration rate which ultimately maximize the water retention and utilization (Syrovy et al., 2015). The performance of potash in the plant growth and development might be due to trigger out the bio-chemical, morphological and physiological processes as a catalyst in the mustard crop plants (Trivedi et al., 2014). In the comparison, the water deficient mustard plant and potash application presented lower emergence and minimum yield related components might be the reason of the declining in the metabolic and functional procedures (Asare and Scarisbrick, 1995). The use of potassium fertilizer during the water stress conditions has been reported as an ameliorating agent to boost up the photosynthetic activity, growth, yield and oil contents in the mustard crop plants (Fanaei et al., 2009). The increasing trend in the number and size of pods might be due to the applied potash which increased the availability of soil moisture and soil aeration resulted in the performance of leaves stomatal conductance and relative water contents. It is observed

Table 2: Effect of potash on yield and oil components of hybrid mustard under water deficit conditions

Potash (kg ha^{-1})	2017-18				2018-19			
	Irrigation water stress							
	Normal	$S_{(Rep)}$	$S_{(Veg+Rep)}$	Mean	Normal	$S_{(Rep)}$	$S_{(Veg+Rep)}$	Mean
Pod fertility (%)								
0	84.00 f	75.00 i	52.93 l	70.64 C	74.00 f	65.00 i	53.17 l	64.06 D
30	89.00 e	80.00 h	64.00 k	77.67 BC	79.00 e	70.00 h	54.00 k	67.67 C
60	98.00 a	90.00 c	87.00 d	91.67 A	89.67 a	81.00 c	80.00 d	83.56 A
90	94.00 b	83.00 g	70.00 j	82.33 B	84.17 b	73.00 g	60.00 j	72.39 B
Mean	91.25 A	82 B	68.48 C		81.71 A	72.25 B	61.79 C	
1000-grain weight (g)								
0	3.18 c	3.16 e	3.08 h	3.14 D	3.17 c	3.16 d	3.07 h	3.13 D
30	3.16 e	3.18 c	3.17 d	3.17 C	3.15 e	3.17 c	3.15 e	3.16 C
60	3.24 a	3.17 d	3.15 f	3.19 A	3.23 a	3.16 d	3.14 f	3.18 A
90	3.22 b	3.14 g	3.17 d	3.18 B	3.21 b	3.13 g	3.16 d	3.17 B
Mean	3.20 A	3.16 B	3.14 C		3.19 A	3.15 B	3.13 C	
Seed yield (kg ha^{-1})								
0	2265.0 d	1650.0 h	1010.0 l	1641.7 D	2250 d	1634.4 h	995.12 l	1626.5 D
30	2450.0 c	1850.0 g	1250.0 k	1850 C	2443.1 c	1835.3 g	1235.6 k	1838 C
60	2658.3 a	2150.0 e	1550.0 i	2119.4 A	2653.1 a	2123.4 e	1535.0 i	2103.8 A
90	2550.0 b	1950.0 f	1430.0 j	1976.7 B	2538.1 b	1944.3 f	1410.12 j	1964.1 B
Mean	2480.8 A	1900 B	1310 C		2471 A	1884.3 B	1293.96 C	
Seed oil content (%)								
0	48.00 f	35.00 j	31.33 k	38.11 D	49.89 f	37.45 j	33.45 k	40.26 D
30	54.00 e	45.00 g	35.00 j	44.66 C	55.67 e	46.97 g	37.11 j	46.58 C
60	63.33 a	61.00 b	41.00 h	55.11 A	65.00 a	62.78 b	43.12 h	56.97 A
90	59.00 c	57.00 d	38.00 i	51.33 B	60.89 c	58.90 d	39.98 i	53.26 B
Mean	56.08 A	49.5 B	36.33 C		57.86 A	51.54 B	38.41 C	
Oil yield (t ha^{-1})								
0	1.09 e	0.58 i	0.32 l	0.66 D	1.12 e	0.61 i	0.33 l	0.69 D
30	1.32 c	0.83 g	0.44 k	0.87 C	1.36 c	0.86 g	0.45 k	0.89 C
60	1.68 a	1.31 d	0.64 h	1.21 A	1.72 a	1.33 d	0.66 h	1.24 A
90	1.50 b	1.11 f	0.55 j	1.05 B	1.55 b	1.15 f	0.57 j	1.09 B
Mean	1.4 A	0.96 B	0.49 C		1.44 A	0.99 B	0.50 C	

Mean values sharing different letters are statistically significant at *p*@ 0.05

Table 4: Benefit cost ratio (BCR) of potash applied soil in hybrid mustard under water deficit conditions

Irrigation water stress	Potash kg ha^{-1}	Total expenditure USD ha^{-1}		Gross income USD ha^{-1}		Net income USD ha^{-1}		Benefit cost ratio USD ha^{-1}	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Normal	0	513	516	1132	1125	619	609	2.21	2.18
	30	545	548	1225	1222	680	674	2.25	2.23
	60	577	580	1329	1327	752	747	2.30	2.29
	90	609	612	1275	1269	666	657	2.09	2.07
$S_{(Rep)}$	0	493	496	825	817	332	321	1.67	1.65
	30	525	528	925	918	400	390	1.76	1.74
	60	557	560	1075	1062	518	502	1.93	1.90
	90	589	592	975	972	386	380	1.66	1.64
$S_{(Veg+Rep)}$	0	473	476	505	498	32	22	1.07	1.05
	30	505	508	625	618	120	110	1.24	1.22
	60	537	540	775	768	238	228	1.44	1.42
	90	569	572	715	705	146	133	1.26	1.23

that nutrient and carbohydrate movement under water stress may be increased due to timely application of potash at reproductive growth stages of mustard crop (Kardam, and Singh, 2005). In-fact, soil applied potash fertilizer ameliorated the presence of moisture availability for crop productivity which enhanced the physiological processes along-with metabolic activities under water stress condition (Ardestani et al., 2011).

The maximum increasing oil contents in mustard crop in this study revealed the reason due to irrigation water regimes at flowering and seed formation stages with potash application may cause in the increasing trend of maximum plant height, number of branches per plant, number of pods per plant, and number of grains per pod (Egilla et al., 2005). On the other-hand, mitigating approach for water stress under potash treatments plants may also be effective tool for increasing the benefit cost ratio of mustard seed crop and oil contents.

CONCLUSION

It is concluded that potash fertilizer application in the soil at 60 kg ha^{-1} is the most effective agronomic and sustainable approach for increasing the mustard crop productivity and oil contents along-with modulating stress effect behavior under water shortage condition.

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Authors' contributions

The author, Professor Nazim Hussain supervisor helped in supervised the research project. The author, Muhammad Ismail conducted the experiment, analyzed the data and wrote the manuscript.

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