Biological Forum – An International Journal **7**(1): 219-224(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

The effects of Solo-potash Foliar application times and Irrigation interval on Quantitative and Qualitative yield of Sorghum

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(Received 21 December, 2014, Accepted 28 January, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: In order to study the effects of Solo-potash foliar application times and irrigation interval on quantitative and qualitative yield of sorghum, an experiment was conducted as a split plot in a randomized complete block design with three replications. Main factors include irrigation levels (6, 12 and 18 days) and sub-plots were Solo potash foliar application times (control (no foliar application), once, twice and three times (30, 45 and 60 days after plant emergence). The results of the analysis of variance showed that 6 days irrigation interval the most profound effect on plant height, panicle length, number of tillers, fresh weight, dry weight, leaf in plant, fresh yield and biological yield. There is no significant difference between 6 and 12 days irrigation interval. Three times foliar application had the most effect on all traits. Interaction between irrigation interval and foliar application showed that Solo-potash foliar application ameliorated drought stress on sorghum, so that three times spraying of Solo-potash on 12days irrigation interval has yield and yield component the same as 6 days irrigation interval. Accordingly, it might be with 3 Solo-potash foliar application and 12 days irrigation interval can be achieved good economic yield.

Keywords: Foliar application, Solo potash, Drought, Forage sorghum

INTRODUCTION

Lack of water is the main limiting factor for crop production in arid and semi-arid area. Agriculture is the major water consumer in the world today which causes and so much consideration has been focused on decreasing water consumption in agriculture (Haile & Tsegaye, 2002). The major problem that agricultural professionals are facing is improving water management in agriculture which causes water, soil and energy protection and meet the need of increasing community food supply (Kassam, *et al.,* 2007). Agricultural producers are always looking for new ways to reduce water consumption through irrigational management. Finding of new ways to reduce water consumption and increase efficacy of water usage in irrigated agriculture in areas with limited water are important (Yazar, *et al.,* 2009).

The activities of more than 50 enzymes are dependent on or stimulated by potassium. Potassium is important on hydrocarbon and protein metabolism, photosynthesis, cell division, cell growth and osmotic pressure (Wang, *et al.,* 2013).

Potassium also is important for regulation of stomata opening and closing, the phloem transportation, onions and cation balance, increasing pest resistance to coldness and drought, increasing disease resistance, nitrogen fixation in legumes and improving the quality of agricultural products (Umar, 2006). It has been reported that potassium probably improves the performance in terms of lack of moisture because of accumulation of potassium in xylem decreases the crude sap osmotic potential. High concentration of potassium ions in Mesophile cells reduces the osmotic potential which is beneficial for decreasing water consumption and so causes lower osmotic potential which results in improvement in water retention.

Jamali *et al.*, (2010) reported that uses of potassium sulfate and zinc sulfate, by increasing the absorption of potassium and zinc causes increasing in protein content, maintaining leaf chlorophyll and efficient photosynthesis. Also by increasing proline concentration in leaf, reduces drought induced osmotic stress and so improves corn resistance against drought stress.

In the case of safflower, it has been observed that in the case of drought conditions in the vegetative stage, plants which were sprayed with zinc and potassium contain higher levels of chlorophyll a concentration, and total soluble sugars than non-sprayed plants (Abedi *et al.*, 2010). Potassium spraying results in osmotic concentration of soluble sugars and proline and thus help maintaining of osmotic pressure in cells which in turn helps plant for drought tolerance (Asgharipour & Heidari, 2011).

Arjomand *et al.* (2000) reported that potassium ion is effective in maintaining the water potential of Sorghum leaf and thus potential of cellular inflammation in water-stressed conditions. Under severe water stress condition application of 300 $kg.ha^{-1}$ potassium fertilizer decreased osmotic potential from -0.3 MPa to -1.7 MPa. Moreover, potassium fertilizer strongly affected leaf rolling index and relative water content maintenance in water stress condition in sorghum plant. Potassium application (300 kg ha^{-1}) increased leaf rolling index from 39% (with non - application potassium) to 47%.

It has been shown that by increasing irrigation intervals from 7 to 13 days during the growing stage of sorghum panicle length, number of spikes per plant, number of grains per panicle, weight of hundred seed and seed activity significantly decreased. So the seed yield decreased 10.5% in 10 days interval and 30% in 13 days interval irrigation. Among the yield and yield compartment, there was a significant difference between different cultivar. Sepideh cultivar had the maximum panicle length and number of kernel in panicle. Grain yield from the highest to lowest amount was belonged to Sepideh, Payam and Kimia cultivars, respectively. As drought stress reduced yield of Payam cultivar (57% reduction in I3) more than other cultivars, Sepideh cultivar had the minimum yield reduction amount (37 percent) and Kimia cultivar had a yield reduction to 44 percent (Tabatabaei & Dehghan Harati 2013).

The effect of potassium on quantity and growth of root in corn, Sorghum and millet in drought conditions was studied by Sayed and Hossein (2010) and reported that biological and grain yield, thousand grain weight, grain filling process and the depth roots penetration under drought stress significantly decreased. However potassium application reduced the adverse effects of drought stress on the mentioned characteristics and increased the root penetration enabled plant to significantly grow its root and penetrating along soil depth under the drought condition. The potassium application under severe water stress, increased the quality which is an important step toward optimal use of water in dry areas.

Solo-potash Kimia contains potassium (50%) and sulfur (18%) and due to its unique properties, has the lowest leaching activity. Solo-potash has specific advantages compared to other potassium fertilizers, such as higher solubility than of potassium sulfate. Sulfate ion causes reduction on soil PH which is very effective in saline soils. While potassium chloride causes plant toxicity and increasing salinity due to chloride containing. According to the advantages of using potassium fertilizer in drought mitigation and since no study was done about the frequency of fertilizer foliar, the aim of this study is to determine the response of forage sorghum to the frequency of Solo-potash foliar application.

MATERIAL AND METHOD

A. Material

This study was done on crops growth in 2012-2013 in on Agriculture and Natural Resources Research Station of Sabzevar (57°39'N, 39°2'E, 980 m above sea level), in Northeast Iran Based on the local meteorological data, the 30 year average rainfall and temperature is 184.5 mm and 17.64 °C respectively. The experiment was established in a sandy clay soil. Table 1 shows some Physiochemical characteristics of the soil.

Table 1: Physico-chemical properties of soil.

Organic matter	Fe	Mn	Cu	Zn	K	Available P	Total N	EC	pH	Sand	Silt	Clay
(%)	mgKg^{-1}							ds.m^{-1}		(%)		
1.12	3.49	4.75	0.64	0.44	259.4	9.25	0.11	1.5	7.8	70	10	20

B. Treatments

The experimental design for this study was a split plot based on randomized complete block design with three replicates. Main plots were irrigation intervals which were 6, 12 and 18 days. Subplots contain times of solo-potash spraying (control), once, twice and three times (30, 45 and 60 days after emergence respectively). Spraying of Solo-potash fertilizer with the concentration of 4 per 1000 contains 50 percent potassium and 18% sulfur.

Sunflower was cultivated in the studied field in previous year. Before preparing the field for fertilizer consumption, the soil samples have been taken randomly from 5 point. Preparation process was done with deep plowing by moldboard. Then crossed disk was met with wheelchair disk for two times to breakdown the aggregates. Due to limitation of farm area the leveling operation was done with the front and rear excavator of tractors instead of loader.

Based on the results of soil test all plots were given 100 kg P205 ha^{-1} as the ammonium phosphate together with half of the N fertilizer (50 kg ha^{-1}) before sowing was uniformly broadcasted and plowed into 15 cm soil. The other half of N fertilizer was applied with irrigation approximately 30 DAP. During the growth period, all plots were weeded manually. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied.

Sorghum variety "Espidfied" was planted on 19 April 2012 at a row spacing of 66 cm with a seeding density of 8 seeds per square meter. To prevent soil crusting and uniform emergence, farm was irrigated after 4 days until the end of project. Irrigation was done with 10 days interval. The distance between the main plots were separated from each other by ridges. The space between replication was 1 m.

C. Plant Harvesting

Plants were harvested in one time when the farm was 20% flowering. At 20% flowering time, to record yield components, 10 plants were selected randomly from each plot and plant height, stem diameter, panicle length, number of leaf, fresh leaf weight, dry leaf weight was calculated. To assess the forage yields, 0.5 m from above and bottom and a lateral row of plots were deleted, and remaining area harvested. Amount of protein and nitrogen were measured with a sample collected from harvested area.

D. Statistical Analysis

After collecting all the data, analysis of variance and mean comparisons (using LSD) were performed by SAS software. Tables and graphs were plotted by software WORD and EXCEL

RESULTS AND DISCUSSION

Analysis of variance showed irrigation interval had significant effect on plant height, number of tillers, and number of leaf on 1% and protein percentage on5% while there was no effect on fresh and dry weight of leaf (Table 2). Mean comparison showed that increasing the irrigation period from 6 to 18 days decreased the sorghum height by 15.36% while no significantly different between the 6 and 12 days irrigation was observed (Table 3). Soil water potential increased with decreasing irrigation intervals due to the use of water by plants (evaporation or transpiration) which cause more availability of water for the roots. Rising in water availability causes more water transfer to the developing organs. Since division and elongation of cell is dependent on the turgor pressure. More water pressure results in increasing turgor pressure which in turn causes increasing cell division and enlargement which increases the height of plant. It is reported that drought stress in sorghum decreased final plant height for 30 cm compared to non-stress conditions (Arjomand, *et al.*, 2000).

Table 2: Analysis of variance table for plant height, number of tillers, number of leaf, Leaf fresh weight, Forage yield and protein.

SOV	df	plant height	number of tillers	number of leaf	leaf fresh Weight	Forage yield	protein
Replication	2	ns	ns	ns	ns	ns	ns
Irrigation	2	**	**	**	ns	*	*
Ea	4						
Application times	3	**	*	**	*	**	ns
Interaction	6	ns	ns	ns	*	ns	ns
Eb	18						
CV	6.77	9.49	27.24	7.27	13.87	16.72	8.08

ns: not significant; (*) and (**) represent significant difference over control at $P < 0.05$ and $P < 0.01$, respectively

Table 3: Effect of irrigation interval onplant height, number of tillers, number of leaf, Leaf fresh weight, Forage yield and protein.

Irrigation interval (Days)	plant height Cm	number of tillers	number of leaf	leaf fresh Weight $g.plant^{-1}$	Forage yield $t.ha^{-1}$	Protein %
6	182.76 a	3.15 a	16.35 a	130.26 a	40.42 a	12.89 a
12	171.48 a	19.35 b	13.15 a	127.04 a	30.73 b	10.5 b
18	154.18 b	17.32 c	12.73 b	110.89 b	30.64 b	10 b

Values followed by the same letter within the same columns do not differ significantly at p = 5% based on LSD.

The highest number of tillers per plant (3.15) were obtained in 6 days-irrigation and the lowest number of tillers per plant (1.53) in 18 days-irrigation. Numbers of tilters was significantly different between 6, 12 and 18 days Irrigation (Table 3). While there was no significant difference between 12 and 18 days irrigation. Tabatabaei and Dehghan Harati (Tabatabaei & Dehghan Harati 2013) also reported that increasing period of irrigation from 7 to 13 days resulted in a significant reduction in panicles of grainy sorghum. However, there was no significant change between 7 and 10-days irrigation. Reduction of the number of panicles per plant due to a decrease in the number of tillers per plant occurred as the first component of yield that decreases the performance of the plant.

Plants grown in normal conditions (6 days irrigation) has 22.21% more leaf per plant than plants grown in conditions of extreme stress (18 days irrigation). No significant difference was observed in the number of leaf per plant among 12 and 18 days irrigation. However, the total numbers of leaf per plant were increased by 25.3% in 12 days-irrigation than 18 days-irrigation (Table 3). Decreasing the number of leaf per plant simultaneously with increasing irrigation intervals can be happened because of two reasons: 1. Failure to produce new leaf which induced by increased soil water potential. 2. Decreased cell division and swelling and loss of the lower leaf or weak leaf which happened in related to increased humidity stress. Sayed and Hossein (Sayed & Hossein, 2010) tested the effect of drought stress on maize, sorghum and millet, and observed that decreasing the number of leaf is related to drought and happened by reducing the height of the stem and no new leaf production.

Mean comparison showed that the highest forage yield was obtained in 6 days-interval irrigation (40.42 $t.ha^{-1}$) which is significantly different with the forage yield which are irrigated in 12 days-interval (30.73 $t.ha^{-1}$) and the irrigation of 18 days (30.64 $t.ha^{-1}$). There was no significant difference between 12 and 18 days irrigation (Table 3). Decreasing in forage yield with increasing in irrigation interval was due to reduced final height and number of leaf per plant.

According Paknejad *et al.*, (2009) decreased water content and stomata closure are the first effects of drought which disturbs procedure of the production of photosynthetic components and so results in reduced yield. Under drought conditions plant closes its stomata thus reduce the amount of intracellular carbon dioxide which leads to a reduction in leaf photosynthesis and construction. It was reported that irrigation after 180 mm evaporation from evaporating than irrigation after 180 mm evaporation from evaporating pan causes a reduction by 68.29 percent per unit area (Khazaei & Fouman, 2012).

Comparison of the means of groups showed that most proteins is in 6 days irrigation which decreased by increasing irrigation intervals (Table 3). Amount of protein is directly related to plant yield. Sarikhani and Razmjoo (Sarikhani & Razmjoo, 2007) also reported that the highest ratio of leaf to stem of forage sorghum causes increasing of protein content of the forage.

Final plant height, number of tillers, number of leaf per plant, fresh forage yield, fresh leaf weight, dry leaf weight and protein content were affected by frequent sprayings of solo-potash (Table 2). Comparison of the means (Table 4) shows that the maximum height was obtained in triple spraying, and the minimum height was observed in control plots. Also there was a significant difference between once sprayed and non-sprayed groups. Given the positive effects of potassium in the regulation of osmotic pressure and increasing the pressure of turgor on plant cells resistance and elongation increasing the amount of potassium by spraying plants directly had a positive effect on plant height. Potassium is the major cation of plant. The main role of potassium is decreasing osmotic potential of stem cells to enhance the turgor pressure, loading and transport of nutrients and water balance of plant. K fertilization is associated with increasing crop growth because of the positive effect of this nutrient in osmotic adjustment, stomatal regulation, photosynthesis, and protein synthesis (Asgharipour & Heidari, 2011). Triple spraying of solo-potash fertilizer increases 36.16% in the number of tillers per plant compares with non-sprayed (Table 4).

Table 4: Effect of foliar application times on plant height, number of tillers, number of leaf, Leaf fresh weight, Forage yield and protein.

Foliar application times	Plant height Cm	Number of tillers	Number of leaf	Leaf fresh Weight $g.plant^{-1}$	Forage yield $t.ha^{-1}$	Protein %
0	152.96 c	1.73 b	11.49 c	107.44 d	30.13 c	10.15 c
1	167.66 b	2 b	13.80 b	117.53 c	30.76 b	11.12 bc
2	174.12 ab	2.24 ab	15.09 a	126.01 b	40.42 a	11.65 b
3	183.15 a	2.72 a	18.91 a	139.94 a	40.43 a	12.01 a

Values followed by the same letter within the same columns do not differ significantly at p = 5% based on LSD.

Although tillering is a cultivar dependent trait but is affected by changing in agricultural management. In this study it seems that more consumption of potassium is effective in maintaining leaf water potential and thus the potential of cell swelling in water stress conditions, which leads to better absorption of food and water from soil, subsequently leads to an increase in the number of tillers per plant.

The maximum number of leaves was observed in 3 times foliar application of solo-potash which was not statistically significant with 2 times spraying. However, once sprayed could not produce adequate number of leaves per plant, 20% increase was observed in the number of leaves per plant compared to non-sprayed (Table 4). Increasing the number of leaves per plant was associated with more frequent of spraying, improved moisture and increasing plant height.

By increasing frequency of spraying, the fresh leaf weight per unit area increased which was statistically significant between treatments. The most fresh leaves weight was observed in triple sprayed while the lowest was observed in the absence of foliar application (Table 4). Given the key role of potassium in enzyme reactions, respiration, absorption and fixation of CO_2, protein synthesis, and its effect on photosynthesis through regulation of stomata activity and water in the plant and increase the resistance of plants against environmental stresses (Wang, *et al.*, 2013) providing potassium in leaves of sorghum has increased the fresh leaf weight. As mentioned in previous sections foliar of potassium has a positive effect on the number of leaves which clarify that foliar of potassium causes increasing the number, volume and length of cells resulting in the increase in fresh leaves weight.

The highest yield of forage obtained in crops with triple sprayed of Solo-potash which was not statistically different from two times spraying with Solo-potashs. Forage yield was lowest in the control (Table 4). Enhanced forage yield causes by increasing frequency of potassium which is due to increased potassium intake. Arjomand *et al.*, (2000) reported that forage sorghum yield is related to the plant height, Which means that the more plant height in during harvest have the more dry matter and the less digestibility of dry matter. Increasing potassium consumption leads to more aerial compartments of plants by adjusting osmotic pressure and improving water condition in leaf and its effect on the opening and closing of stomata (Mehrandish, *et al.*, 2012). It has been reported that potassium increased drought tolerance in plant through the enhancement of water uptake by the roots. The more potassium application the more strongly roots attract water from the soil. Potassium also enhances rapid seedling development and increased crop yield. The results show that triple spray of Solo-potash causes obtaining of the highest amount of protein but no significant difference was observed between once and twice sprayings(Table 4).

Analysis of variance showed that the interaction between the frequency of foliar of solo-potashs and irrigation interval on fresh leaf weight was significant (Table 2). The highest fresh leaf weight was obtained on triple spraying and 6 days-irrigation. Increasing of irrigation interval decreased significantly fresh leaf weight, However, these could be increased significantly by increasing solo-potash spraying times under normal (6 days irrigation interval) as well as water stress conditions(18 days irrigation interval) (Fig. 1).

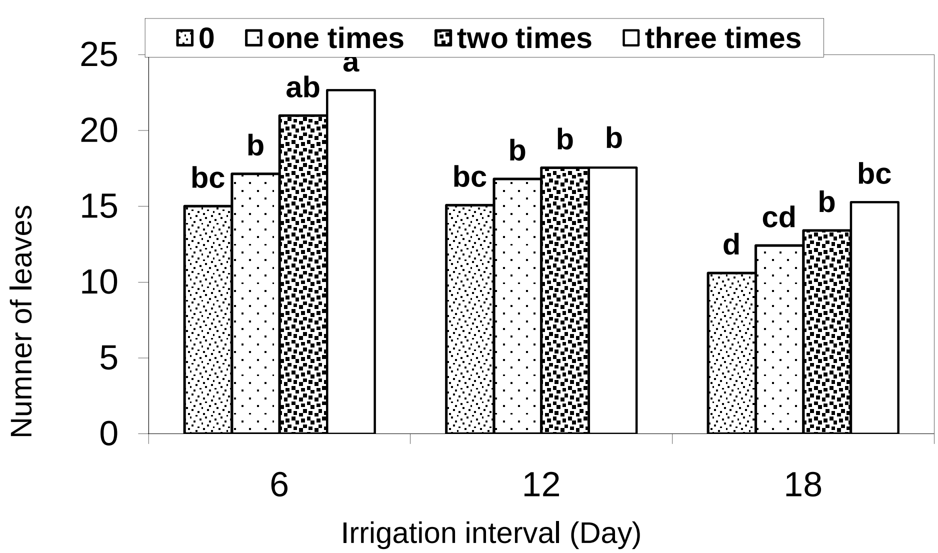

Fig. 1. Interaction between irrigation interval and foliar application times on number of leaves.

It was reported that water stress decreased leaf K content and declination of K content could be recovered to some extent by application of high level of potassium (Umar, 2006). In our study increasing of frequency of K foliar application was increased K content in leaf and improved stomatal resistance, relative water content, NRA, chlorophyll and proline contents which might improve the overall plant water status and metabolism and increased number of leaf in plant and finally increased fresh leaf weight. Increased application of K+ has been shown to enhance photosynthetic rate, plant growth, yield and drought resistance in different crops under water stress conditions. K-fed plants maintained higher leaf water potential, turgor potential and relative water content and lower osmotic potential as compared to untreated plants (Kant, *et al.*, 2002).

CONCLUSION

The results from this study on sorghum, 3 times of foliar pplication of K fertilizer within the sufficiency range (4 ‰) was beneficial in alleviating the effect of drought on the forage yield and vegetative growth of sorghum, since forage yield and vegetative growth increased with increasing of frequency of foliar application of K under water deficit. Increasing of irrigation interval from 6 to 18 days significantly decreased all plant attributes, however 2 or 3 times K spraying improve yield of sorghum, so that forage yield in 6 days irrigation interval as well as 12 days irrigation interval with 3 times foliar application of Solo-potash.

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