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Water Use Efficiency, Growth and Yield of Wheat Cultivated Under Competition with *Setaria*[1]

*Eficiência do Uso da Água, Crescimento e Rendimento do Trigo Cultivado em Competição com **Setaria***

IHSAN, M.Z.[2], EL-NAKHLAWY, F.S.[2], and ISMAIL, S.M.[2]

ABSTRACT - Understanding the critical period of weed competition is indispensable in the development of an effective weed management program in field crops. Current experiment was planned to evaluate the critical growth period of *Setaria* and level of yield losses associated with delay in weeding in rain-fed drip irrigated wheat production system of Saudi Arabia. Field experiment was conducted to evaluate the effect of weeding interval (07-21, 14-28, 21-35, 28-42 and 35-49 days after sowing) and drought stress (75% and 50% of field capacity) on *Setaria* growth, wheat yield and water use efficiency. Season long weedy check and well-watered (100% FC) plots were also maintained for comparison. Weeding interval and drought stress significantly ($p \leq 0.05$) affected the growth and yield of *Setaria* and wheat. Drought stress from 75% to 50% FC resulted in reductions of 29-40% in *Setaria* height, 14-27% in *Setaria* density and 11-26% in *Setaria* dry biomass. All weeding intervals except 35-49 DAS significantly suppressed *Setaria* growth as compared with control. Delay in weeding increased weed-crop competition interval and reduced wheat yield and yield contributors. Therefore, the lowest yield of 1836 kg ha^{-1} was attained for weeding interval of 35-49 DAS at 50% FC. Water use efficiency and harvest index increased with decreasing FC levels but reduced with delay in weeding. Correlation analysis predicted negative association of *Setaria* density with wheat yield and yield contributors and the highest negative association was for harvest index (-0.913) and water use efficiency (-0.614). Early management of *Setaria* is imperative for successful wheat production otherwise yield losses are beyond economical limits.

Keywords: weed control, competition interval, *Setaria viridis*, field capacity, arid land.

*RESUMO - Compreender o período crítico de concorrência entre plantas daninhas é indispensável para o desenvolvimento de um programa eficaz de controle delas nas plantações. Este experimento teve como objetivo avaliar o período crítico de crescimento da **Setaria** e o nível de perdas de rendimento, associado à demora da capina das plantas daninhas, em um sistema de produção de trigo com irrigação por gotejamento de chuva na Arábia Saudita. O experimento em campo foi conduzido para avaliar o efeito do intervalo de capina das plantas daninhas (07-21, 14-28, 21-35, 28-42 e 35-49 dias após a semeadura) e do estresse hídrico (75 e 50% da capacidade de campo) sobre o crescimento da **Setaria**, o rendimento do trigo e a eficiência do uso da água. Os cultivos bem irrigados (100% de CC) e submetidos à verificação de plantas daninhas ao longo de toda a estação foram mantidos para comparação. O intervalo de capina das plantas daninhas e o estresse hídrico afetaram, de forma significativa ($p \leq 0,05$), o crescimento e o rendimento da **Setaria** e do trigo. O estresse hídrico de 75 a 50% de CC causou reduções de 29 a 40% na altura da **Setaria**, 14 a 27% em sua densidade e 11 a 26% em sua biomassa seca. Todos os intervalos de capina, exceto o de 35 a 49 DAS, suprimiram significativamente o crescimento da **Setaria**, em comparação à testemunha. O atraso da capina elevou o intervalo de concorrência com plantas daninhas e reduziu o rendimento da produção do trigo e colaboradores do rendimento. Portanto, o menor rendimento (1.836 kg ha^{-1}) foi obtido no intervalo de capina de 35 a 49 DAS em 50% de CC. A eficiência do uso da água e o índice de colheita*

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[2] Department of Arid Land Agriculture, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University P.O. Box 80208, Jeddah: 21589, Saudi Arabia, <meeransaim@gmail.com>.

*elevaram-se com a redução dos níveis de CC, porém reduziram com o atraso da capina das plantas daninhas. A análise de correlação previu associação negativa da densidade da **Setaria** com o rendimento do trigo e colaboradores do rendimento, e a maior associação negativa foi do índice de colheita (-0,913) e eficiência do uso da água (-0,614). O manejo precoce da **Setaria** é essencial para o sucesso de rendimento do trigo. Se não houver o manejo precoce, as perdas de rendimento podem exceder os limites econômicos.*

Palavras-chave: controle de plantas daninhas, intervalo de concorrência, *Setaria viridis*, capacidade de campo, terra árida.

INTRODUCTION

Wheat (*Triticum aestivum*) is a prominent cereal crop and staple food for one third of global inhabitants (FAO, 2015). It is the most consumed grain cereal in Saudi Arabia with per capita consumption of 88 kg per year. In 2014-15, wheat was cultivated on an area of 83 thousand hectare (-17% reduction in area) with total yield of 425 thousand MT (-29% reduction in yield) (Mousa, 2014). Saudi wheat production continues its drastic decline, as the government enforces its policy to phase-out wheat cultivation subsidy and lack of farmer's knowledge and expertise in crop management and weed control. The increasing demand and decreasing production is alarming, as demand continues to increase at a rate of 3.2% per annum. Moreover, fresh water availability is the major limitation for wheat production in the Peninsula. Arid features of this region bring multiple abiotic stresses, such as drought, salinity, heat, low soil fertility and organic matter (Oliveira et al., 2013). Along with various abiotic stresses, weeds are the major biotic constraint to wheat production accounting up to 48% yield losses (Oerke & Dehne, 2004). Weeds interfere with natural growth of the crop by competing for natural resources such as water, space, light, nutrient and air (Khaliq et al., 2013; Mahmood et al., 2015). Wheat yield losses are directly related to density, species, time of emergence, and weed-crop competition interval (Hussain et al., 2015). A strong direct relationship exists between competition duration and pressure on crop yield loss (Fahad et al., 2014).

Green foxtail (*Setaria viridis*) is a C4 summer annual grassy weed with decumbent stem and graminoid growth habit (Rao et al., 1987; Jiang et al., 2013). Its stem can grow up to two meters in length, bearing dense inflorescence, compact spike with up to 20 centimeters length. Spikelets are subdivided into three stiff bristles and fertile lemmas are finally cross wrinkled (Brutnell et al., 2010). It has fibrous root system and reproduces by seed. Worldwide distribution of *Setaria* is observed, as wide range of habitat (cropland, fallow, pasture, barren uncultivated land, parks and vacant lots), favors its growth and reproduction. Our recent studies (El-Nakhlawy et al., 2015) on drought and salinity management for sustainable wheat production have identified Green foxtail infestation as a major biotic limitation causing significant yield loss.

Plant species competitive ability was affected by its environmental factors (Gioria & Osborne, 2014). Moisture, temperature and nutrient levels influence germination, growth, and competition. Green foxtail was found more competitive with late sown wheat than with early seeded wheat. No herbicide has been previously registered for *Setaria* control in Saudi Arabia. Its continuous emergence and fast growth habit in drip irrigated wheat fields was creating significant trouble in farm operations and causing enormous yield losses. No previous data was available on its critical growth period and economic threshold level in wheat crop under arid land conditions.

Understanding *Setaria*-wheat interference in well watered and drought stressed conditions is critical for planning an efficacious, integrated and sustainable weed management program in rain-fed drip irrigated systems. Knowledge on crop-weed competition interval and yield losses can further opens the agronomic, ecological and biological options for weed suppression (Hussain et al., 2015).

Therefore, the present field experiment was performed under arid land conditions in order to investigate *Setaria* competition interval interaction on wheat growth, yield and water use efficiency. It is believed that the outcome of this study will ensure significant contribution in determining optimum time for *Setaria* control and contribute to notable yield recovery by timely weed management.

MATERIALS AND METHODS

Site description

A field experiment was conducted at Arid Land Agriculture Research Station Hada Al-sham (21°32'36" N, 39°0'22" E), King Abdulaziz University, Jeddah, KSA, during 2013-14 to examine the interaction of *Setaria viridis* weeding interval (WI) and drought stress applied as different field capacities (FC) in wheat crop. Soil of experimental site belonged to sandy texture with 0.43 mg kg^{-1} N, 0.17 mg kg^{-1} P, 2.3 mg kg^{-1} K, 8.35 pH and 0.48% organic matter. Agro-climatological data during growing season (December-April) recorded 12-40 °C minimum-maximum temperature, 55-63 minimum-maximum relative humidity and 33 mm total rainfall.

Experimentation

A previously cultivated land with high *S. viridis* infestation was selected for experimentation. Prior to installation of drip irrigation, field was ploughed twice by tractor-mounted plough followed by planking. Drip irrigation system was installed with drip to drip distance of 9 cm, drip to line distance of 10 cm and line to line distance of 20 cm. Sub plot size was 3.2 m x 4 m. Wheat variety "Yocora Rojo" was planted on 5th December 2013, with manual driven pore. High seeding rate of 175 kg ha^{-1} was used due to arid land conditions, and row to row distance was maintained at 20 cm. Water soluble fertilizers were fertigated as N:P:K (200;150;100 kg ha^{-1}) in the form of DAP, Urea and NPK complex in split doses at tillering, booting and spike initiation stages. No pesticide was used for insect or disease control. Crop was harvested at second week of April at physiological maturity.

Experimental design and treatment

The experiment was laid out as randomized complete block design with split plot arrangement of treatments, comprising of drought stress and WI. Drought stress was applied as 100%, 75% and 50% of their FC while five WI were plotted under each FC. Weeding interval denoted time period for which plots were cleaned and kept weed free. Five WI comprised of 07-21 days after sowing (DAS), 14-28 DAS, 21-35 DAS, 28-42 DAS and 35-49 DAS were applied along with control (weedy check). No weed except *S. viridis* was allowed to grow throughout the crop-growing season. Auto control drip irrigation system (Rain Bird *ESP-ME Enhanced modular controller*) was set to supply calculated amount of water to each plot. Flow of the used dripper was 2 L h^{-1} so the time of water application was changed on weekly bases with respect to crop growth stage and climatic conditions. Soil moisture contents were determined through gravimetric method on weekly bases to estimate expected difference in applied and required amount of water to maintain soil at required FC. Auto control system was run on daily bases with continuous water supply from the main source.

Observations

At the start of each WI (1st to 5th week after planting), *Setaria viridis* height (cm), density (plant m^{-2}) and dry biomass (g m^{-2}) were measured. These parameters were further used to measure the *S. viridis* persistence index (SPI) (Mishra & Mishra, 1997).

$$SPI = \frac{\text{Dry matter of Setaria in treated plot}}{\text{Dry matter of Setaria in control}} \times \frac{\text{Setaria count in control}}{\text{Setaria count in treated plots}}$$

Wheat growth and yield parameters were recorded at crop physiological maturity. Plant height was recorded by measuring scale from ten randomly selected plants from each plot. Spike bearing tillers were differentiated from nonbearing unfertile/grain less spikes and classified as productive tillers. Topmost leaf width from base, middle and top were averaged and multiplied with length to measure flag leaf area. Grain yield and yield contributors, spike length, spikelet per spike and 1000 grain were manually recorded. The same procedure was adopted both for spike length measurement and plant height. Spikelet per spike were manually counted from ten randomly selected spikes and averaged. Thousand grain weight and economical yield were calculated and adjusted at 12% moisture content. Wheat economical yield and biological yield were used to compute harvest index (HI). Water use efficiency (WUE) for each FC was examined as kg grain ha^{-1} mm^{-1}. Interactions of increasing weeding density with delay in WI were drawn against yield loss. This yield loss was correlated to maximum *Setaria* density that resulted in sharp decline at each FC level.

Statistical analysis

The experiment was replicated thrice with main plot FC and sub plot WI. Data were subjected to two way analysis of variance (ANOVA) and means of main effects and their interactions were separated with Fisher LSD at $p \leq 0.05$ and $p \leq 0.01$ (Steel et al., 1997).

RESULTS AND DISCUSSION

Setaria growth and persistence

S. viridis height, density, dry biomass and persistence index presented significant variation to applied levels of FC and WI. Main effect of FC was significant at $p \leq 0.05$ while WI and FC x WI were highly significant at $p \leq 0.01$ for all studied weed attributes. Application of drought stress reduced weed height, density and dry biomass while enhanced weed persistence index. Severe drought stress (FC 50%) resulted in the maximum suppression in weed attributes as compared with well-watered condition. Compared with 50% FC, a reduction of 29-40% in plant height, 14-27% in weed density and 11-26% in dry biomass was recorded at 75% FC (Table 1). All WI except 35-49 DAS have significantly suppressed *Setaria* growth traits as compared to control. Weeding interval from 07-21 DAS presented the highest weed control through significant reduction in height, biomass and density of *S. viridis*. Delay in weeding contributed towards weed intensification and biomass accumulation. An overall reduction of 15-26% in weed density and biomass were documented with each week delay in weeding from germination until 6th week of planting. However, non-significant effect of WI was apparent after 7th week of weeding irrespective to drought stress levels. Interaction of severe drought stress and first WI presented the highest level of *Setaria* control. *Setaria viridis* persistence index was the lowest at first WI and its interactions with both drought and well-watered conditions were non-significant (Figure 1A). Intensification in weed competition interval favored *Setaria* persistence index irrespective of applied field capacity levels. The highest persistence index

Table 1 - Effect of drought stress and weeding interval on *Setaria* height, density and biomass accumulation in wheat

Treatment	*Setaria viridis* height (cm)			Weed density (m^{-2})			Weed dry biomass (m^{-2})		
	FC								
	100%	75%	50%	100%	75%	50%	100%	75%	50%
Control	121.33 a	86.08 c	73.66 de	249.33 a	213.34 b	182.66 d	282.33 a	251.94 b	208.66 d
07-21 DAS	28.33 j	22.03 k	17.66 k	57.66 m	47.66 n	42.66 o	119.30 j	85.31 l	76.04 m
14-28 DAS	46.00 i	42.66 c	34.31 j	75.33 k	71.66 k	64.66 l	174.66 f	112.33 k	91.08 l
21-35 DAS	71.01 de	62.66 g	44.08 i	99.64 h	86.33 i	82.30 j	192.04 e	155.07 g	127.66 i
28-42 DAS	83.00 c	64.09 fg	52.66 h	155.66 e	112.31 g	95.66 h	253.30 b	209.33 d	146.66 h
35-49 DAS	110.05 b	75.33 d	69.39 ef	188.66 c	155.33 e	146.33 f	255.07 b	215.66 c	176.05 f
Field Capacity (FC)	*	*	*	*	*	*	*	*	*
Weeding Interval (WI)	**	**	**	**	**	**	**	**	**
FC × WI	**	*	*	**	*	*	*	**	*
LSD (p≤0.05)	5.99	-	-	3.82	-	-	6.29	-	-
CV	6.18	-	-	7.89	-	-	8.16	-	-

*, ** represent significance at $p \leq 0.05$ and $p \leq 0.01$ probability level, respectively. ns represents no significant difference. LSD; least significant difference, CV; coefficient of variation.

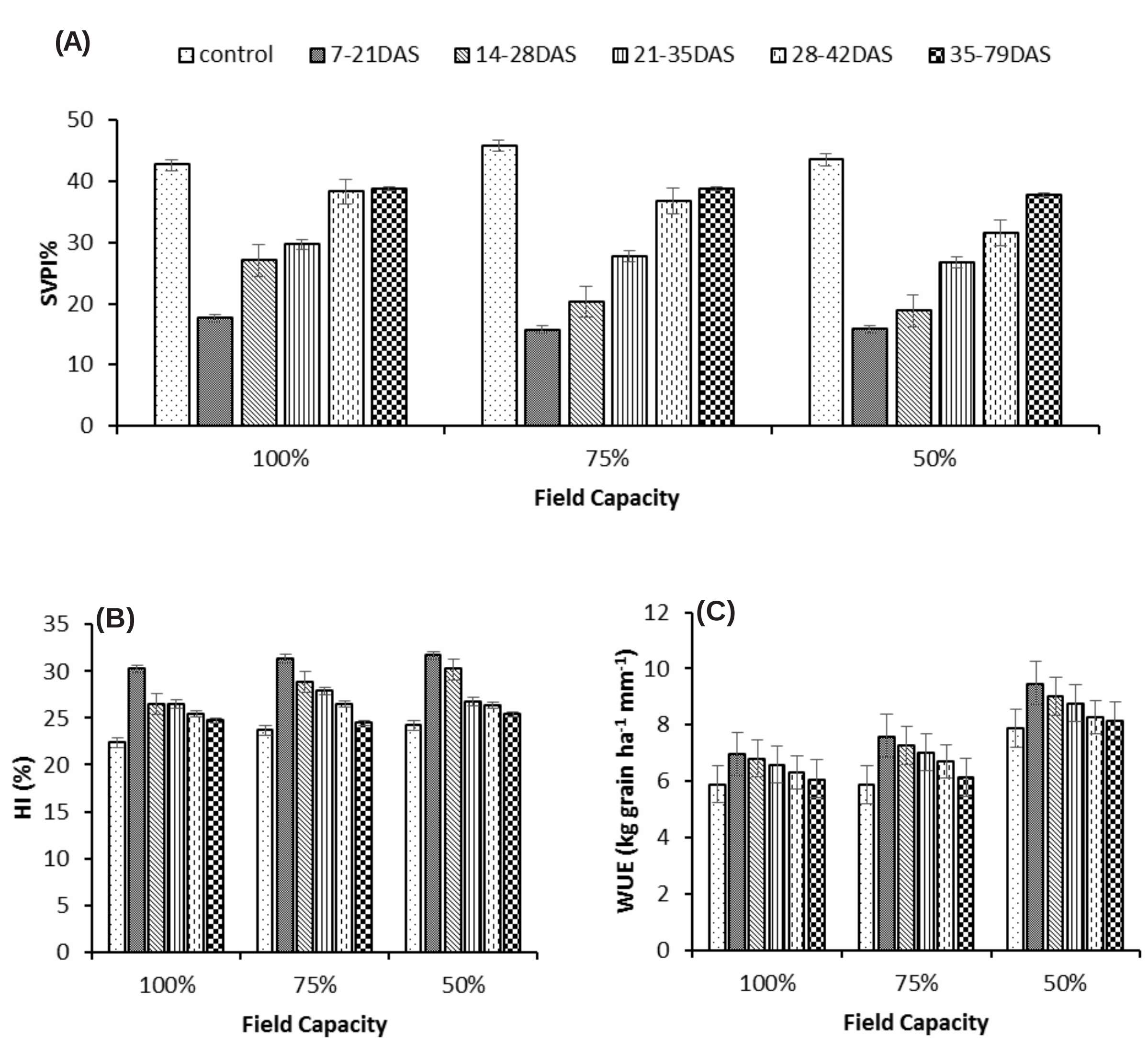

Figure 1 **-** *Setaria viridis* persistence index percentage (SVPI%) (A), harvest index percentage (HI%) (B) and water use efficiency (WUE) (C) for six weeding intervals and three field capacities. Verticle lines represent standard error bars.

was recorded for the plots where *Setaria* was allowed to grow for the longest period of time.

Wheat yield and yield components

Wheat growth, yield and yield components were greatly dependent on moisture availability and time of weeding for *Setaria* control. Effect of FC was highly significant $p \leq 0.01$ for plant height, productive tiller, flag leaf area, 1000-grain weight and grain yield. Effect of WI was highly significant $p \leq 0.01$ for unproductive tiller, 1000-grain weight and grain yield. Interaction of FC x WI were significant $p \leq 0.05$ for unproductive tiller, flag leaf area, 1000-grain weight, grain yield and non-significant $p \leq 0.05$ for plant height, productive tiller, spike length, spikelet per spike and harvest index (Table 2, Figure 1). Drought stress significantly reduced all studied traits except unproductive tillers and harvest index that were increased. The highest effect of drought stress was recorded on flag leaf area that presented a reduction 22-36% at 75-50% FC levels. Spikelets per spike and stem height were the least affected traits under studied FC levels. Growth and yield attribute presented significant reductions with delay in weeding. Weeding from 1st to 3rd week after sowing allowed

Table 2 - Effect of drought stress and weeding interval on wheat growth, yield and yield components

Field capacity	Treatment	Plant height (cm)	Productive tiller	Unproductive tiller	Flag leaf area	Spike length	Spikelets per spike	1000 grain wt (g)	Grain yield (kg ha^{-1})
100%	Control	61.34 e	246 d	79 efg	23.12 gh	11.23 d	12.66 e	30.71 ef	2573 f
	07-21 DAS	73.04 a	330 a	30 k	33.67 a	14.33 a	17.33 a	38.86 a	3040 a
	14-28 DAS	73.33 a	306 b	46 jk	30.40 b	13.67 b	15.66 b	36.81 b	2970 b
	21-35 DAS	69.07 b	309 b	54 ij	29.26 c	12.66 c	14.66 c	35.84 b	2871 c
	28-42 DAS	66.66 c	279 c	74 fgh	27.97 d	12.33 c	13.66 d	34.52 c	2751 d
	35-49 DAS	63.09 d	240 d	76 efgh	24.67 f	10.66 d	13.33 d	32.38 d	2654 e
75%	Control	55.33 e	201 e	105 bc	17.95 k	8.66 e	12.02 c	25.56 hi	1952 l
	07-21 DAS	66.24 a	294 a	46 jk	26.03 e	12.66 a	14.33 a	31.15 e	2526 f
	14-28 DAS	64.00 b	267 b	70 ghi	23.84 fg	11.33 b	13.33 b	29.82 f	2415 g
	21-35 DAS	63.04 b	237 c	88 def	21.94 i	10.33 c	13.27 b	28.48 g	2336 h
	28-42 DAS	59.66 c	216 d	98 cd	20.26 j	9.33 d	13.31 b	27.94 g	2229 i
	35-49 DAS	58.07 d	207 de	106 bc	20.30 j	8.61 e	12.13 c	26.51 h	2042 k
50%	Control	51.08 e	138 d	146 a	14.76 m	7.25 d	9.65 d	21.22 l	1774 n
	07-21 DAS	62.01 a	234 a	62 hij	22.25 hi	10.19 a	12.33 a	26.62 h	2134 j
	14-28 DAS	60.03 b	204 b	76 efgh	20.53 j	9.33 b	11.30 b	25.13 ij	2028 k
	21-35 DAS	56.33 c	183 c	92 cde	18.25 k	8.33 c	10.63 c	24.33 j	1972 l
	28-42 DAS	54.33 d	171 c	120 b	17.78 k	7.12 d	10.51 c	22.74 k	1861 m
	35-49 DAS	51.66 e	144 d	142 a	16.27 l	6.66 d	9.68 d	21.41 l	1836 m
Field capacity (FC)		**	**	**	**	*	*	**	**
Weeding interval (WI)		*	*	**	*	*	*	**	**
FC × WI		ns	ns	*	*	ns	ns	*	**
LSD (p≤0.05)		1.51	14.86	16.67	0.92	0.56	0.60	1.08	54.42
CV		7.78	6.65	11.90	4.43	5.78	4.95	6.07	4.66

*, ** represent significance at $p \leq 0.05$ and $p \leq 0.01$ probability level, respectively. ns represents no significant difference. LSD; least significant difference, CV; coefficient of variation.

minimum weeds to establish thus improved wheat growth and yield components. Magnitude of WI with FC interaction was variable depending upon the level of drought stress and studied trait. Interaction of WI at 07-21 DAS x 100% FC favored most of the studied traits as the highest flag leaf area, 1000-grain weight and grain yield were achieved for this treatment. Delay in weeding (35-49 DAS) produced the highest number of unproductive tillers at severe drought stress level (50% FC). The least spike length, spikelet per spike, 1000-grain weight and grain yield were documented in un-weeded plots where the highest level of drought stress was applied (50% FC). Early weeding intervals up to 4th week after sowing recovered these yield attributes by controlling *Setaria* below economic threshold level. Delay in weeding resulted in unrecoverable damage to growth and yield, since lowest yield (1,836 kg ha^{-1}) was attained for WI of 35-49 DAS at 50% FC.

Water use efficiency and correlation matrix

Main effects and interaction between FC and WI were highly significant for WUE. WUE increased with increasing FC levels, but decreased with delay in weeding. The minimum WUE (5.90 kg grain ha^{-1} mm^{-1}) was attained in un-weeded but well watered plots, while early-weeded plots with 50% FC depicted the highest WUE (9.49 kg grain ha^{-1} mm^{-1}) (Table 2). A FC of 75% and WI after 35 DAS did not bring any significant improvement as compared to 50% FC and WI of 7-21 DAS. *Setaria viridis* density and dry biomass and wheat yield components were strongly associated with grain yield. Data explained a negative relationship of weed density to all growth and yield components and the highest negative association was documented against harvest index (-0.913) and water use efficiency (-0.614) (Table 3). Correlation matrix estimated above 35% disparity in WUE in response to productive tiller, flag leaf area, 1000-grain weight, grain yield while harvest index produced medium positive correlation to WUE (Table 3). All studied growth and yield components estimated medium to strong correlation among each other, except for harvest index that indicated very weak positive correlation. Negative consequences of *Setaria viridis* for flag leaf area was pointed out by the negative influence on wheat grain yield by *Setaria* density. Estimated level of yield loss was the highest for 100% FC plots that were weeded at 6th week after emergence. At 50% FC, *Setaria* density of 170 plants predicted same level of yield loss as for 190 and 250 plants for 75% and 100% FC levels, respectively. Sharp decline in grain yield curve at 50-75% FC was due to decreased wheat competition potential with *Setaria* density at low soil moisture contents (Figure 2).

Soil moisture content and competition interval significantly influenced *Setaria* density, dry biomass, height and persistence index. The highest weed density and dry biomass was attained in well-watered plots where weeds were allowed to compete for longer period of time. Under water deficit conditions, significant reduction in weed density was associated with reduced green foxtail germination and growth and improved germination and emergence of wheat (Peterson & Nalewaja, 1992). Delay in *Setaria* emergence in 50% FC plots were noticeable that decreased the time of competition between *Setaria-wheat* and allowed the wheat crop to establish canopy cover. Yield losses in severe drought stressed plots were due to limited moisture supply rather than *Setaria* competition. Weed-crop competition was also influenced by climatic conditions, since *Setaria* is a C4 species and wheat is a C3 crop. Arid features of experimental area (salinity, temperature, radiation and drought) favored *Setaria* germination and growth, as season long emergence of *Setaria* was noticeable (Rizal et al., 2013).

The competition interval within 07-35 DAS appeared to be the most critical period that resulted in drastic reduction in grain yield and yield components. Plots where weeds were allowed to grow during this interval documented the least number of productive tiller, flag leaf area, spike length, number of spikelet and grain yield. Khaliq and Matloob (2011) reported that weed competition beyond 20 DAS resulted in sharp decline in grain yield and yield attributes. Chauhan & Johnson (2010) recorded a grain yield loss of 24% for weed competition of 28 DAS and season long competition forced the maximum yield loss of 89% in rice. The period (07-35 DAS) coincide with tillering and canopy cover, thus maximum number of productive tiller loss is reported during this period that ultimately leads to lower yield (Yaduraju & Mishra, 2004). The relationship between weeding interval to *Setaria* density was exponential and weeding interval to grain yield was polynomial. While, yield increment was directly proportional to time duration period of weed free plots (Wang et al., 2010).

Effect of WI, FC and their interaction was highly significant for flag leaf area. Reduction in flag leaf area was more prominent for 50% FC compared with 75% or 100% FC. This severe decline in leaf area resulted in lower vegetative growth but greater water use efficiency. Drought stress affects leaf area, rate of leaf emergence, rate of leaf

Table 3 - Correlation matrix for *Setaria viridis* density and wheat grain yield, yield components and water use efficiency

	Setaria density	Productive tiller	Flag leaf area	1000 grain weight	Grain yield	Harvest index	Water use efficiency
Setaria density	1	-0.36349	-0.33278	-0.18213	-0.16327	-0.91308	-0.61365
Productive tiller		1	0.96975	0.95723	0.93982	0.38308	-0.37284
Flag leaf area			1	0.97908	0.96845	0.33041	-0.35071
1000 grain weight				1	0.99031	0.17377	-0.50757
Grain yield					1	0.15532	-0.48713
Harvest index						1	0.61844

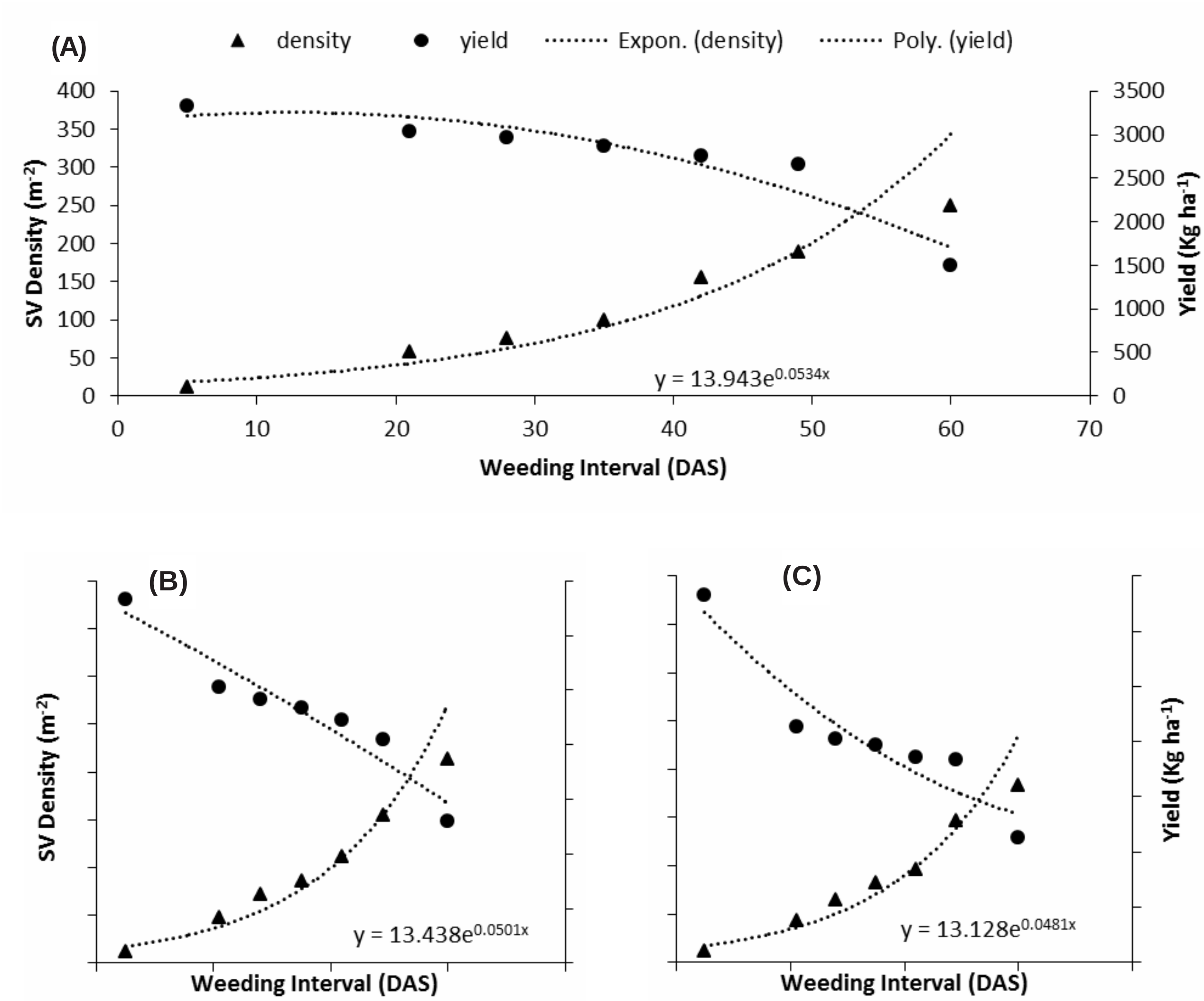

Figure 2 - Estimation of yield loss for weeding interval and weed density at 100% FC (A), 75% FC (B) and 50% FC (C). Value at X-axes 0, 10, 20, 30, 40, 50 and 60 represent weeding interval for 0-10 DAS, 07-21 DAS, 14-28 DAS, 21-35 DAS, 28-42 DAS, 35-49 DAS and control respectively. Triangle and circle are markers for weed density and grain yield, while their trend lines are exponential and polynomial. FC; field capacity, SV; *Setaria viridis* and DAS; days after sowing. Verticle and horizontal axis are the same for b and c, as used for a.

expansion and tiller development. Wheat is a C3 plant and exhibit inefficient growth at elevated temperature, probably owing to increased photorespiration induced by higher temperature (Lara & Andreo, 2011). On contrary, green foxtail is a C4 weed and exhibit better growth at elevated temperature thus resulted in higher competition with wheat crop. *Setaria* gained more height compared with wheat crop and this might also have distorted wheat growth through reduced light availability by shading (Hussain et al., 2004). Reduced *Setaria* infestation under dry conditions is favored by good soil tilt and high temperature. Season long germination might have also contributed in higher weed density thus retarded WUE of wheat at each growth stage.

Both, drought stress (applied as different FC) and *Setaria* competition interval resulted in significant yield loss in wheat crop. Magnitude of yield loss increased with decreasing FC and increasing weed-crop competition interval. Productivity of wheat is largely dependent on timely and effective weed control. This effective weed control requires knowing on the critical period of weed-crop competition and level of yield loss associated with delay in weeding. Knowledge on the critical growth period (07-35 DAS) of *Setaria* infestation could help in planning manual or chemical weed control strategy for wheat crop. No herbicide is registered in Saudi Arabia against *Setaria* control and data regarding its critical growth period will help to improve selection, dose, timing and frequency of treatment for effective control.

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