Pure Appl. Biol., 7(1): 85-92, March, 2018
http://dx.doi.org/10.19045/bspab.2018.70011

Research Article

Influence of source limitation on physiological traits of wheat

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Citation
Shah Khalid, Fazal Munsif, Imranuddin, Nadia, Faisal Nadeem, Shamsher Ali, Farman Ghani and Muhammad Idrees. Influence of source limitation on physiological traits of wheat. Pure and Applied Biology. Vol. 7, Issue 1, pp85-92. http://dx.doi.org/10.19045/bspab.2018.70011

Received: 13/09/2017 Revised: 27/12/2017 Accepted: 28/12/2017 Online First: 10/01/2018

Abstract

To investigate the effect of source limitation on physiological traits of wheat crop, a field experiment was conducted in complete randomized block design having three replications, at Amir Muhammad khan campus, Mardan, Khyber Pakhtunkhwa, Pakistan, during winter season, 2015. At anthesis stage eight source reduction treatments (normal plant (N) as control, removal of 2nd + 3rd leaf, removal of 2nd + 3rd + 4th leaf, removal of 2nd+4th+5th leaf, removal of 4th + 5th + 6th leaf, removal of 4th + 5th leaf, removal of flag leaf (FLR), removal of all leaves (ALR) were applied. The results indicated that all source limitations significantly affected all observed parameters. All the treatments comparison was found significant except ALR vs FLR. ALR vs FLR was found non-significant for all parameters except for awns length. ALR and FLR had significantly decreased productive spikelets spike^{-1} (5.24, 6.51 %, respectively), florets spikelet^{-1} (17.0%, 10.4%), grains spike^{-1}, grain/straw ratio (58.8%, 50.0%), while increased non-productive spikelets, respectively (112.9%, 85.1%) and awn length (25.7%, 16.5%) and spike straw weight (10.80%, 15.9%) while in contrast, the removal of 2nd +3rd leaf significantly increased florets spikelet^{-1} 6.38 % and decreased non-productive spikelets spike^{-1} by 33.3% as compared to normal plants. From the results it is concluded that wheat crop at anthesis stage is source limited.

Keywords: Anthesis; Flag leaf; Source reduction; Wheat crop

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop throughout the world and is grown on about 200 Million ha worldwide, with production of more than 600 million metric tons/annual **[1].** Worldwide wheat production must increase 2 % yearly till 2020 to balance the strain of fast growing population **[2].** Worldwide wheat is used is stable food, 35 % of the people used wheat as food, which supplies 29 % of energy needs. Wheat supplies the largest share to the cereals market **[3]**. The photosynthate distribution during grain filling considerably affects the grain yield **[1]**. At anthesis stage, photosynthesis ability of the leaves and storage capacity of the grains is the major reason for reduced yield **[4]**. Sink-source relationships strongly effect dry matter production in crops **[5, 6]**. Number of grains spike^{-1} decreased considerably by removal of all leaves after anthesis stage **[5]**. Source reduction can decrease wheat yield by 30 to 40%, in most conditions grain filling in wheat was more influenced by sink **[7, 8]**.

The carbohydrates that are necessary for grains development are delivered from two sources, leaves and spike **[9, 10]** and by the remobilization of assimilate to the grains **[11]**. The transportation of assimilates from the source to the sink strongly depend upon the production and consumption ability of the source and sink respectively. If they are not in a balance relation the yield will decrease. An appropriate ratio between the source and the sink is a main component to attain promising yields **[12]**. Effective transport of photosynthate from source (leaves) to growing spikelets (sink) is needed for grain filling and high yield.

Materials and methods

An experiment was conducted on the influence of source limitation on physiological traits of wheat, at Amir Muhammad khan Campus, Mardan, Khyber Pakhtunkhwa, Pakistan in 2015. The crop was sown at end of November, 2015. Field was ploughed with a cultivator three times and then with a rotavator to breakdown the clods to prepared a fine seedbed to ensure uniform and good germination. Seeds were sown in lines with a recommended isolation (30 cm row to row). Fertilizers were applied at recommended rate i.e. total phosphorus and half nitrogen was applied at sowing time while remaining half of nitrogen was applied after first irrigation. Weeds were removed manually. Irrigations were applied according to the crop need. The experiment was composed of three replications with RCB design. There were eight subplots per replications. Data were recorded from each plots by selected ten plants in each plot. The crops were harvested at harvest maturity at the end of April, 2016. At anthesis stage eight source reduction treatments (normal plant (N) as a control, removal 2^{nd} + 3^{rd} leaf, removal of 2^{nd} + 3^{rd} + 4^{th} leaf, removal of 2^{nd}+4^{th} +5^{th} leaf, removal of 4^{th} + 5^{th} + 6^{th} leaf, removal of 4^{th} + 5^{th} leaf, removal of flag leaf (FLR), removal of all leaves (ALR) were applied. Data were recorded on the following parameters, productive spikelet spike^{-1}, non-productive spikelet spike^{-1}, awns length, florets spikelet^{-1}, spike straw weight and grain to husk ratio.

Data recording and handling

Productive spikelets

Productive spikelets spike^{-1} was recorded by counting productive spikelets spike^{-1} of ten randomly selected spikes in each treatment, and were then averaged.

Non-productive spikelets spike^{-1}

Data on non-productive spikelets spike^{-1} was recorded by counting empty spikelets spike^{-1} of ten randomly selected spikes in each plot.

Florets spikelet^{-1}

Data were taken by counting florets in each spikelet of ten randomly selected spikes in each plot and the averaged.

Awns length (cm)

Awns length (cm) was calculated by measuring the length of upper, middle and lower awns of ten randomly selected spikes through ruler and then averaged.

Spike straw weight (g)

Straw weight was calculated by the following formula:

Spike straw = spike weight – grain weight

Grain /husk ratio

Grain/ straw ratio was determined by the following formula:

Grain/straw ratio = Grain weight ÷ Spike straw

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) according to the methods described by **[13]** and means between treatments were compared by least significant difference (LSD) at $P \leq 0.05$.

Results and discussion

Florets spikelet^{-1}

Statistical analysis of the data showed that source limitation was highly significantly affected florets spikelet^{-1} (Table 1). Mean square data showed that control vs rest, normal vs flag leaf remove (N vs FLR) and normal vs all leaves remove (N vs ALR) were found significant, while the FLR vs ALR was observed non-significant (Table 2). High number of florets/ spikelet was observed in removal of 2th+3rd leaf, followed by removal of 4th +5th+6th leaf, followed by the all other treatments which was statistically similar except FLR and ALR, in which lower number of florets was observed (Table 1). Percent reduction data (Table 3) showed that most of the treatments considerably reduced florets spikelet^{-1} especially in case of ALR and FLR, (17.0 and 10.2%) respectively, except removal of 2nd+3rd, 2nd+3rd+4th and 2nd+4th+5th (6.3, 1.9 and 1.6) respectively. The decreased in in the case of ALR and FLR was might be due to the decreased in photosynthetic area, which directly affect photosynthate production and it transportation to spikes. In wheat, main photosynthetic organs are leaves; principally the flag leaves. Mostly lower leaves are shaded by the upper ones and maximum solar absorption occurs in flag leaves. Thus, flag leaf and photosynthetic area above flag leaf indicated the importance of these structures to increase grain yields **[14]**. The flag leaf blade and total photosynthetic area above the flag leaf node have positive correlation with weight of grain plant^{-1} **[15]**. The increased in florets spikelets^{-1}, in case of 2th+3rd leaf removal, might be due the decrease of the shaded leaves in lower portion. During anthesis in wheat crop 1st leaves at bottom was almost died due to senescence and have not working anymore only the 2nd and 3rd leaves are alive which completely shaded by the upper leaves in crop community, so it have no sufficient photosynthate to compensate respiration, and become depended upon the upper sunny leaves.

Awns length (cm)

Statically analysis of the data revealed that source reduction significantly affected awns length. Significant variation was found in control vs rest, ALR vs N, N vs FLR and ALR vs FLR. Mean data showed that higher awns length was observed in case of ALR followed by FLR, followed by the remaining treatments, which are statistically similar (Table 2). Percent reduction data (Table 3) showed that awns length was increased by all treatment particularly by ALR and FLR (25.7cm and 16.5 cm respectively). The increased in awns length in case of ALR and FLR might be due to the severe reduction of photosynthetic area, its might be a restorative phenomenon in wheat for increasing photosynthetic area, the spike photosynthesis and the role of awns in grain filling also suggested by **[16]**, they reported reduction in grain yield when awns were removed 10 days after anthesis. Awns also play a dominant role as an important transpiration and photosynthetic organ in ear. It possesses a large surface area, sometimes can equal that of the ground surface, and can exceed that of the flag leaf blade in wheat. It can work well at the time of heading, while some of the leaves are already senescent or heavily shaded. The pathway for assimilation movement from awns to the kernels is minimal which makes awns an ideally place for light interception and CO2 uptake **[17]**.

Table 1. Mean data of florets/spikelet, awns length, productive spikelets spike^{-1}, non-pro. spikelets spike^{-1}, spike straw weight and grains/husk ratio and as affected by different source reduction at anthesis stage in wheat crop

Treatments	Description	Florets / spikelet	Awns length(cm)	Productive spikelets	Non-productive spikelets	Spike straw weight (g)	Grains / husk ratio
T1	(control)Normal plant	4.54 ab	5.52 c	18.43 a	1.80 d	0.63 a	3.36 ab
T2	2^{nd} +3^{th} leaf removed	4.83 a	5.52 c	18.60 a	1.20 e	0.63 a	3.33 ab
T3	2^{nd} +3^{rd} +4^{th} leaf removed	4.63 ab	5.63 c	18.26 ab	2.80 c	0.59 b	3.38 a
T4	2^{nd} +4^{th} +5^{th} leaf removed	4.62 ab	5.56 c	18.26 ab	2.60 c	0.63 a	2.91 b
T5	4^{th} +5^{th} +6^{th} leaf removed	4.36 b	5.66 c	18.20 ab	2.36 c	0.58 c	3.24 ab
T6	4^{th} +5^{th} leaf removed	4.46 ab	5.58 c	18.06 ab	2.86 b	0.62 ab	3.07 ab
T7	Flag leaf removed	4.06 c	6.43 b	17.46 b	3.33 ab	0.57 e	1.68 c
T8	All leaves removed	3.76 d	6.94 a	17.23 c	3.83 a	0.57 e	1.38 c
$Lsd_{0.05}$		0.46	0.37	0.85	0.52	0.05	0.05

Table 2. Mean square data of the florets/spikelet, owns length, pro. Spikelets/spike, non-pro. Spikelets/spike, spike straw weight and grains/husk ratio and as affected by different source reduction at anthesis stage in wheat crop

SOV	Florets/ spikelet	Awns length (cm)	Pro. spikelet/ spike	Non-productive spikelet spike^{-1}	Spike straw weight (g)	Grain/husk ratio
Replication	0.228^{ns}	0.06^{ns}	0.708^{ns}	0.084^{ns}	0.002^{ns}	0.069^{ns}
Treatment	0.355^{**}	0.845^{**}	0.673^{*}	2.068^{**}	0.006^{**}	1.922^{**}
Control vs Rest	0.059*	0.392*	0.460*	2.194**	0.0043*	1.102*
N vs FLR	0.341^{*}	1.25^{**}	2.160^{**}	3.527^{**}	0.004^{**}	4.250^{**}
ALR vs FLR	0.135^{ns}	0.385^{*}	0.082^{ns}	0.375^{ns}	0.000^{ns}	0.132^{ns}
ALR vs N	0.905^{**}	3.026^{**}	1.402^{*}	6.202^{**}	0.005^{**}	5.881^{**}
Error	0.070	0.046	0.237	0.089	0.001	0.071
CV(%)	5.96	3.94	2.69	11.44	0.002	9.54

Note: N, FLR, ALR, represent normal plant, flag leaf remove, and All leaves remove, respectively.
* and ** represent significant at 5% and 1 % probability level, respectively

Table 3. Percent reduction in florets spikelet^{-1}, awns length, productive and non-productive spikelets spike^{-1}, spike straw weight (g) and grains/husk ratio and as affected by different source reduction at anthesis stage in wheat crop

Treatments	Description	Florets spikelet^{-1}	Awns length(cm)	Productive spikelets spike^{-1}	Non- productive spikelets spike^{-1}	Spike straw weight (g)	Grains/ husk ratio
T1 (control)	Normal plant	-	-	-	-	-	-
T2	2+3 leaf removed	-6.38	-1.92	-0.9	33.33	-1.1	0.99
T3	2+3+4 Leaf removed	-1.98	-1.44	0.9	-55.56	10.1	-0.59
T4	2+4+5 leaf removed	-1.69	-0.85	1.99	-44.44	-0.5	13.38
T5	4+5+6 leaf removed	3.89	-2.54	1.27	-31.48	18	3.57
T6	4+5 leaf removed	1.69	-1.21	0.9	-59.26	0.5	8.62
T7	Flag leaf removed	10.49	-16.55	6.51	-85.19	8.5	50.05
T8	All leaves removed	17.09	-25.72	5.24	-112.96	9.5	58.87

Productive spikelet spike^{-1}

Statistical analysis of the data showed that source limitation significantly affected productive spikelets spike^{-1} and significant variation was found in control vs rest, normal vs flag leaf removed (N vs FLR) and normal vs all leaves removed (N vs ALR) respectively, while the contrast between flag leaf removed vs all leaves removed (FLR vs ALR) was observed non-significant (Table 1). Higher number of productive spikelets spike^{-1} (18.4, 18.6) were observed in case of normal plant and removal of 2nd+3rd leaf, respectively followed by remaining treatments, which were statistically similar except FLR and ALR. Percent reduction data (Table 2) revealed that all source reduction treatments ware progressively decreased productive spikelets spike^{-1}, especially in case of ALR and FLR (5.2 and 6.5), respectively except removal of 2nd + 3rd leaf, in which about 1% increase was observed (Table 2). The decrease would be due the deficiency of the photosynthate, on the removal of all leaves or flag leaf, it may cause severe deficiency of assimilate. Similar results were reported by **[15]** who reported that removal of leaves particularly flag leaf significantly reduced productive spikelets spike^{-1}.

Non-productive spikelets

Statistical analysis revealed that all the source reductions treatment highly significantly affected non-productive spikelets spike^{-1} (Table 1). Highly significant variation ware found in control vs rest, normal vs flag leaf removed (N vs FLR) and all leaves removed vs normal (ALR vs N) while the contrast between flag leaf removed and all leaves removed (FLR vs ALR) was not significant (Table 1). The data showed that fewer non-productive spikelets were found in removal of 2th+3rd leaf and more non- spikelets spike^{-1} were observed in ALR followed by FLR and 4th +5th leaf removed while the remaining treatments found to be statistically at par with each other's except normal plant. Percent reduction showed that most of treatments increased non-spikelets spike^{-1} as compared to normal, especially by ALR and FLR (112.9 and 85.2%) respectively (Table 3) except removal of 2nd+3rd leaf in which 33.3 % reduction was observed. The increased in non- productive spikelet spike^{-1} might be due to decreased transportation of the photosynthate. These results showed the importance of all leaves particularly flag leaf photosynthesis in grain filling, because flag leaf are the upper most leaf of the wheat crop, which received maximum sunlight and produced higher amount of photosynthate, and also due to nearness to the grains (sink) translocation of the assimilates also quickly occurred. The present results are in line with finding of **[15]** who reported that removal of flag leaf significantly increase non-productive spikelets spike^{-1}. Leaves, especially flag leaf as source of photosynthates production and the most powerful factors on the growth and number of the seeds **[16].**

Grain/ husk ratio

Mean square data revealed that grain/ spike straw ratio highly significantly affected by source reduction, all contrasts i.e., control vs rest, N vs FLR and N vs ALR were found to be highly significant except FLR vs ALR (Table 1). Higher grain/ spike straw ratio was observed in case of removal of 2nd+3rd+4th leaf , followed by normal and 2nd+3rd leaf removal, while the lowest was observed in case of ALR followed by FLA. Percent data revealed that most of the source reduction treatments were markedly decrease grain/husk ratio particularly ALR and FLR except in 2+3+4 leaf removed, which showed about 0.59% increased grain/husk ratio is compered to normal plant. The decrease in grain/ spike straw ratio due to source reduction especially in case of ALR and FLR might be due to lower dry matter accumulation in the sink, due to less photosynthates availability.

Spike straw weight (g)

Statistical analysis of the data showed that source limitation was significant affected spike straw weight, as well as all the contrasts were also found to be highly significant except ALL vs FLR (Table 2). Mean data showed that similar high straw weight was recorded for normal, removal of 2nd +3rd leaf and removal of 2nd+4th+5th leaf (0.6g) while the lowest was observed in case of ALR and FLR, (0.5g) percent reduction revealed that all the treatment decrease straw weight except removal of 2nd +3rd leaf and 2nd+3rd+5th leaf, which showed an increase of 1.1 and 0.5%, respectively. Source limitation increased stem and spike contribution to grains. The decreased in spike straw weight might be due to the decrease in leaf photosynthate, which switch on contribution of the spike photosynthesis to grain during grain filling, reserves contribution to seed filling process. Similar results were reported by **[18]** who reported that the demand by the growing kernel is increasing and current assimilation is diminishing due to natural senescence and the effect of various stresses.

Conclusion

This study concludes that wheat yield is more source limited at anthesis stage under irrigated conditions of Pakistan. Substantial reduction occurred with flag leaf removal and leaves near to flag leaf.

Authors' contributions

Conceived and designed the experiments: F Munsif & S Khalid, Performed the experiments: S Khalid, Analyzed the data: F Munsif & S Khalid, Contributed materials/ analysis/ tools: I Din, Nadia, F Nadeem, S Ali, M Idrees, Wrote the paper: S Khalid.

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