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Evaluation of Source and Sink Physiological Limitation on Grain Yield and Some Agronomic Traits in Promising Bread Wheat Genotypes

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ABSTRACT

In order to study of sink and source limitation and determine of remobilization of dry matter in 20 bread wheat genotypes including three modern cultivars (Urum, Zare and Mihan) and 17 promising genotypes, two field experiments were conducted in Agricultural Research Station of Miandoab in West Azerbaijan during 2012-2013 and 2013-2014 cropping seasons. The genotypes were evaluated in a randomized complete block design with three replications. Treatments of control, flag leaf removal and removal half of each spike was applied in order to study of sink-source limitation in normal condition. Flag leaf removal and removing of the rest leaves (source limitation) decreased grain yield by an average of 25% and 8% respectively. Removal of flag leaf had more affected on grain yield, biological yield, 1000 grain weight and source limited. Removal half of Spikelet per spike (sink limitation) increased grain weight in C-89-8, C-89-14 and Mihan genotypes. Low sink and source limitation was shown in C-89-4, C-89-10 and C-89-14. These genotypes showed the highest grain yield because of more seed per spike, high TKW. Average means of source limitation (34.5%) was more than sink limitation (16.3%) in this genotypes. Positive significant correlation showed between remobilization of dry matter with grain yield (r=0.564, P<0.01) and 1000 kernel weight (r=0.446, P<0.05). The negative correlation of grain yield with kernel weight, seed per kernel and remobilization of dry matter indicated this trait can be used for identifying of high yield potential in bread wheat genotypes

Key words: *Grain yield, sink-source limitation, wheat genotypes*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important food resources. Wheat provides 20% of energy and 30% of human protein sources. Wheat is cultivated in a wide range in agricultural lands in the world[24]. Approximately one third of the world population is using this plant as main food[13]. Based on FAO statistic data base, the world wheat production in year of 2030 must be going to 818 million ton[10]. Therefore, improving attainable yields of wheat requires knowledge of yield-determining physiological processes such as adaptation to environments with a broad range of climatic and edaphic variation, diversity in plant traits and plasticity in source-sink.

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Grain yield is a complex factor in wheat and influenced by many factors, such as environmental condition, plant genetic and affect traits of vegetative growth in plant[2]. Biomass production is related to leaf surface and leaf strength in plant[15]. To location of photo-assimilate Source and for location of assimilates storage in plant is Sink[22]. Movement of photo-assimilates from sources (leaves, spikes and stems) to sinks (grains) are dependent on both source and sink strength[11]. Blum *et al*[6]., concluded that, one way to increase grain yield in wheat is manipulation of sink (grain) capacity. Movement of photo-assimilates from source to sink are depend on capacity of source products and sink uptakes.

Nonexistence balance of sink and source cause to decreasing of grain yield in plant[1]. Correct equilibrium of sink and source is a fundamental factor to achievement of optimal grain yield in plants[17]. Grain weight is an important factor in yield production in wheat genotypes. Allocated of more photo-assimilate to sink or grains is one of the methods to achievements to high yield in wheat genotypes[21]. Increasing of grain weight and grain yield of wheat cultivars under removal of some spikelets in each spike was expressed in other reports[7,16]. Some researchers have expressed that the grain yield of wheat is limited by the source[8,25] or sink strength[23], while some researchers have emphasized the concurrent limitations of source and sink[3]. More researchers have been shown contribution of stem reserves in wheat grain filling about 20-30% in normal condition[14,28]. If assimilate supply to the grain decreases, source limiting is going to intensify. Old cultivars had been further restrictions to source limitation, but new semi dwarf wheat cultivars due to more grain per spike and high grain weight have less restriction[9]. The objectives of this research are to determine the roles of source and sink limitations on formation of grain yield, its components and understanding the source-sink relations in order to provide appropriate physiological traits for improving breeding programs in different improved wheat genotypes in normal condition.

MATERIALS AND METHODS

Two field experiments were conducted in Agricultural Research Station of Miandoab in West Azerbaijan Miyandoab in the North West of Iran (46˚ 7' E and 36˚ 48' N) during 2012-2013 and 2013-2014 cropping seasons. The soil was a silty (45.8% silt, 28.7% clay) with a pH=8.4 and Ec=0.48 dS/m. The experiment was laid out in a RCB-Design with three replications and 20 bread wheat (*Triticum aestivum* L.) genotypes including three new released cultivars and 17 promising genotypes (table 1).

Table 1: Name/Code and Pedigree of 20 used bread wheat genotypes

No.	Code	Pedigree
1	Check	Urum
2	Check	Zare
3	Check	Mihan
4	C-89-1	Owl//Ombul/Alamo
5	C-89-2	Bow"s"/Crow"s"//Kie"s"/Vee"s"/3/MV17
6	C-89-3	Fdo 2062
7	C-89-4	Zarrin*2/Gaspard
8	C-89-5	Babaga
9	C-89-6	Pyn*2/Co725052/3/Kauz*2/Yaco//Kauz
10	C-89-7	Alvand*2/Gaspard
11	C-89-8	Shi#4414/Crows"s"//Gk Sagvari/Ca8055
12	C-89-9	308.02.2/Weaver//F362K2.121
13	C-89-10	Zander/3/Kauz*2/Yaco//Kauz
14	C-89-11	Gascogne/Col. no.3625//Zarrin
15	C-89-12	Fdo 4085
16	C-89-13	Fdo 1104-2
17	C-89-14	Fdo 5121
18	C-89-15	Fdo 6087
19	C-89-16	Bez/Nad//Kzm(Es85-24)/3/Ptzniska/…
20	C-89-17	Kleiber/2*Fl80//Donsk.Poluk./3/Ks82W409/…

Each plot included six rows 20cm apart and five meters long. Seeds were sown at a density of 450 seeds m^{-2} on 15th October. Based on soil analysis, All plots received 25 kg ha^{-1} urea (46%N), 15 kg ha^{-1} $ZnSO_4.7H_2O$, 85 kg ha^{-1} KH_2PO_4, 100 kg ha^{-1} $HPO_4(NH_4)_2$ before planting and 140 kg ha^{-1} urea at tillering and pre-anthesis. At maturity, number of grain per spike and grain weight was calculated at 10 spikes of genotypes.

For the application of sink and source limitations during flowering in the middle rows of each plot for each cultivar 15 similar stems were selected and following three treatments were applied for five out of 15 stems: (1) control, (2) removing flag leaves (source limitation treatment) and (3) removing spikelet on one side of each spike using the forceps (sink limitation).

In order to study of source and sink limitation, used treatments of removing 50% spikelet/spike (formula 1) and flag leaf for sink limitation (formula 2) in 10 plants respectively[19]. Relation for both limitation is S.L = (a/b-1)×100

(1) In Source limitation formula
    a is grain weight in removing spikelet
    b is grain weight in check
(2) In Sink limitation formula
    a is grain weight in removing flag leaf
    b is grain weight in check

Amount of dry matter remobilization in plant was calculated plant dry matter weight in stage of anthesis and maturity stage and the following formula were used for Remobilization contribution[20].

(3) Remobilization contribution = (amount of retransfer/grain yield) × 100
(4) Current photosynthesis Ratio = 100 - Remobilization contribution

Analysis of variance performed using PROC GLM in the SAS software (SAS Institute Inc, Carry, NC, USA). The comparison of the means was done by Turkey`s test at 5% probability level. Correlations between trails were determined using SAS PROC CORR. The classification of genotypes using SPSS software by Ward algorithm based on squared Euclidean distances. Weather conditions during the crop season are presented in table 2.

Table 2: Mean of precipitation, temperature and relative humidity data in North West of Iran

Month	Average of temperature (˚C)		Precipitation (mm)	Relative humidity (%)	
	Minimum	Maximum		Minimum	Maximum
Oct.	7.1	25.6	4.9	31	85
Nov.	4.9	16.8	87.3	24	83
Dec.	0.7	9.3	56.6	21	67
Jan.	-4.4	5.7	20.8	24	74
Feb.	0.4	11.2	25.5	20	67
Mar.	1.3	13.8	35.6	23	76
Apr.	3.9	19.5	27.8	22	84
May.	7.3	21.4	22.2	46	93
Jun.	11.0	28.6	1.9	50	92
Jul.	15.2	32.9	0.0	40	86
Aug.	15.3	32.7	0.0	38	90
Sep.	11.2	31.6	3.8	32	83

RESULT AND DISCUSSION

Genotypes in terms of yield and its components

Analysis of variation for genotype showed significant differences for grain yield, grain number/spike, 1000 grain weight, harvest index and biological yield at 1% statistical probably level and number of spikelet/spike at 5% statistical probably level (table 3). According to the results of mean comparisons, the highest grain yield was observed for genotypes C-89-4, C-89-10 and C-89-14 with 9746, 9760 and 9852 kg/ha respectively. Two genotypes of C-89-4 and C-89-10 were shown the highest biological yield as well. The highest 1000 grain weight with 56.5 gr and grain number in spike belonged to genotype C-89-4 (table 4). Due to high 1000 grain weight, number of grain and number of spikelet per spike and biological yield, this genotype had the highest grain yield.

Genotypes in terms of physiological traits

Analysis of variation showed significant difference among genotypes for all traits at $p<0.01$ (table 5). Removing of flag leaf and all other leaves decreased grain weight by an average of 24.4% and 7.6% respectively.

Source limitation in removal spikelet treatments

Removal of spikelet from one side of spike increasing grains weight in the remaining grains in the spike by an average of 15.7%. The most 1000 grain weight in treatment of spikelet removing was shown in genotype of C-89-4 with 61.7 gr and the least was shown in C-89-2 with 43.3 gr (table 6). The genotype of C-89-14 with 31.1 gr had the highest source limitation in comparing with other genotypes. The lowest percentage of source limitation was shown in genotypes of Urum, C-89-4, C-89-6 and C-89-9 with average of 9.2 gr (table 6). Several studies showed that in the new bread wheat genotypes increasing of seed per kernels cause of increasing more competition for grain filling[4]. It seems there is a positive correlation between grain yield and source limitation in normal condition.

Sink limitation in flag leaf removal

Sink limitation was studied with removal of flag leaf and all leaves except flag leaf. Results showed elimination of flag leaf had the most sink limitation in genotypes. The least sink limitation belonged to genotypes C-89-8 with 63.8% and the highest were showed in Zareh and C-89-17 by an average of 22% (table 6). Average amounts of 1000 grain weight in treatments of flag leaf removal and all leaves except flag leaf were 33.8 gr and 41.3 gr respectively. It showed importance of flag leaf in grain filling stage. Moreover, speed and during time of grain filling have relation with grain weight in plan[12]. In the other words, grain filling period was affected by amount and speed of storage matter transfer and current photosynthesis on this trait[26].

Remobilization contribution

Analysis of variation showed significant difference among genotypes for remobilization contribution at $P<0.01$ statistical probably level (table 5). This result was agreement with Mirtaheri *et al*[18]., and Yang *et al*[29]. The highest remobilization of dry matter belonged to genotypes C-89-4 and C-89-14 by an average of 46%, and the lowest ones was seen in C-89-10 with 14.3% (table 6). This result was similar to Voltas *et al*[27]. The highest current photosynthesis was shown in genotypes C-89-10 (90.7%) and the lowest in Mihan cultivar, C-89-4 and C-89-14 with 54%. based on Blum *et al*[6]., existence of suitable genetic diversity for nourished matter remobilization, could be used in development of grain yield in wheat.

Table 3: Analysis of variation for plant characteristics of wheat genotypes

S.O.V	Df	MS					
		Grain yield	1000 grain weight	Grain spike^{-1}	Spikelet spike^{-1}	Biological yield	Harvest index
Year	1	19.06*	584.37**	349.76ns	68.34*	67.78ns	879.88*
Error 1	4	1.92	17.18	137.63	7.04	24.94	102.63
Genotype	19	3.33**	171.42**	155.39**	5.62*	17.89**	85.86**
Genotype×Year	19	0.194ns	0.405ns	25.59ns	1.42ns	1.32ns	11.89ns
Error 2	76	0.579	8.666	35.98	2.88	3.578	14.85
CV%		9.3	6.5	17.3	11.0	7.9	7.7

* and ** significant at 1% and 5% probability levels and ns non significant

Table 4: Mean comparison of plant characteristics of wheat genotypes

Genotype	Grain yield (t.ha^{-1})	1000 grain weight (gr)	Geain spike^{-1}	Spikelet spike^{-1}	Biological yield (gr/plot)	Harvest index (%)
Oroum	7.114 c	49.2 cd	37.6 a-d	15.8 abc	13.4 f	50.9 c-f
Zareh	7.596 bc	45.9 d-g	37.1 a-d	14.4 bc	14.0 ef	52.1 b-f
Mihan	8.007 bc	52.8 b	37.4 a-d	16.5 ab	14.7 c-f	52.1 b-e
C-89-1	8.138 bc	44.2 efg	36.7 a-d	15.8 abc	16.7 bcd	47.2 f
C-89-2	8.075 bc	34.0 j	30.7 de	13.7 c	15.6 b-f	49.9 def
C-89-3	7.857 bc	40.0 hi	36.2 bcd	15.8 abc	15.3 b-f	49.1 def
C-89-4	9.746 a	56.5 a	38.1 a-d	17.2 a	19.5 a	47.7 ef
C-89-5	7.786 bc	47.1 c-f	36.6 a-d	15.4 abc	15.1 c-f	48.8 def
C-89-6	8.106 bc	49.1 cd	26.5 ef	15.5 abc	16.6 b-e	47.3 f
C-89-7	8.037 bc	45.7 def	31.1 de	14.4 bc	15.6 b-f	49.7 def
C-89-8	7.857 bc	44.3 efg	23.3 f	14.4 bc	15.4 b-f	48.8 def
C-89-9	7.980 bc	45.3 d-g	40.7 abc	15.4 abc	15.1 c-f	50.4 c-f
C-89-10	9.760 a	43.4 fgh	35.7 bcd	15.4 abc	19.4 a	48.0 ef
C-89-11	8.188 b	47.7 cde	31.5 de	14.3 bc	13.6 f	58.4 a
C-89-12	8.314 b	39.8 hi	31.4 de	14.3 bc	14.6 def	55.0 abc
C-89-13	8.525 b	38.6 i	44.4 a	17.2 a	16.9 bcd	48.5 def
C-89-14	9.852 a	50.8 bc	41.9 ab	15.8 abc	17.7 ab	53.6 a-d
C-89-15	8.211 b	39.1 i	32.5 cde	16.5 ab	14.0 ef	56.6 ab
C-89-16	7.557 bc	41.6 ghi	33.3 cde	15.1 abc	15.3 b-f	47.1 f
C-89-17	7.595 bc	47.6 cde	31.0 de	15.8 abc	17.2 abc	41.8 g
LSD 5%	0.875	3.39	6.90	1.95	2.17	4.43
LSD 1%	1.161	4.49	9.15	2.59	2.89	5.88

Means in each column followed by similar letter(s) are not significantly different at 5% probability level, using Duncan`s Multiple Range Test

Table 5: Analysis of variation for physiological traits in wheat genotypes during 2013-2014

S.O.V	Df	MS						
		Source limitation	Sink limitation	Remobilization contribution	Current photosynthesis ratio	1000 Grain weight in flag leaf removal	1000 Grain weight in rest leaves removal	1000 Grain weight in half Spike removal
Year	1	75.51ns	337.41*	285.30*	1435.0**	403.33*	700.83*	1203.3**
Error 1	4	24.11	20.14	18.97	18.97	18.33	59.17	38.33
Genotype	19	247.70**	589.50**	581.30**	581.3**	98.44**	192.76**	178.95**
Genotype×Year	19	114.91**	1.40ns	88.63ns	88.63ns	12.11ns	7.85ns	17.37ns
Error 2	76	32.988	64.275	76.993	76.993	13.947	17.939	20.789
CV%		25.3	23.2	17.7	12.0	11.0	12.0	8.8
Mean		16.3	34.5	31.7	73.3	33.8	41.3	51.7

* and ** significant at 1% and 5% probability levels and ns non significant

Table 6: Mean comparison for physiological traits in wheat genotypes during 2013-2014

Genotype	Source limitation (%)	Sink limitation (%)	Remobilization contribution (%)	Current photosynthesis ratio (%)	1000 Grain weight in flag leaf removal (gr)	1000 Grain weight in rest leaves removal (gr)	1000 Grain weight in half Spike removal (gr)
Oroum	11.1 def	40.0 b-e	24.0 def	81.0 abc	38.3 ab	50.0 a	58.3 ab
Zareh	22.3 bc	22.0 i	32.5 cd	72.5 cd	38.3 ab	43.3 cd	55.0 abc
Mihan	18.6 bcd	26.5 ghi	46.1 a	58.9 f	38.3 ab	48.3 ab	58.3 ab
C-89-1	16.1 c-f	31.0 d-i	23.6 def	81.4 abc	33.3 cde	38.3 ef	51.7 b-e
C-89-2	30.9 a	24.7 hi	31.6 cd	73.5 cd	26.7 g	31.7 h	43.3 f
C-89-3	23.8 b	46.3 b	44.2 ab	60.8 ef	28.3 fg	38.3 ef	50.0 c-f
C-89-4	10.0 ef	38.9 b-f	46.4 a	58.6 f	40.0 a	50.0 a	61.7 a
C-89-5	11.5 def	28.7 f-i	14.7 ef	90.3 ab	38.3 ab	46.7 abc	50.0 c-f
C-89-6	9.1 f	42.8 bc	23.4 def	81.6 abc	36.7 abc	43.3 cd	53.3 bcd
C-89-7	13.6 def	33.6 c-h	31.5 cd	73.5 cd	35.0 bcd	41.7 de	46.7 def
C-89-8	11.4 def	63.8 a	32.6 cd	72.4 cd	31.7 def	45.0 bcd	58.3 ab
C-89-9	9.2 f	39.9 b-e	28.2 d	76.8 c	31.7 def	38.3 ef	46.7 def
C-89-10	12.8 def	29.0 f-i	14.3 f	90.7 a	33.3 cde	36.7 fg	51.7 b-e
C-89-11	17.6 b-e	37.3 b-g	42.7 abc	62.3 def	33.3 cde	46.7 abc	55.0 bc
C-89-12	15.3 c-f	27.5 ghi	32.8 cd	72.2 cd	30.0 efg	35.0 fgh	46.7 def
C-89-13	13.5 def	37.0 b-g	23.1 def	81.9 abc	30.0 efg	33.3 gh	45.0 ef
C-89-14	31.1 a	41.3 bcd	46.3 a	58.7 f	30.0 efg	38.3 ef	58.3 ab
C-89-15	17.4 b-e	27.2 ghi	35.0 bcd	70.0 cde	31.7 def	35.0 fgh	46.7 def
C-89-16	16.0 c-f	29.9 e-i	34.6 bcd	70.3 cde	31.7 def	38.3 ef	45.0 ef
C-89-17	14.1 def	22.3 i	26.1 de	78.9 bc	40.0 a	46.7 abc	51.7 b-e
LSD 5%	6.60	9.22	10.09	10.09	4.29	4.87	5.24
LSD 1%	8.76	12.23	13.38	13.38	5.70	6.46	6.96

Correlation between studied traits

Correlation coefficient was calculated between grain yield, yield components and remobilization contribution (table 7). Grain yield showed positive and significant correlation with number of spikelet (r=0.582**), grain weight in spike (r=0.566**), 1000 grain weight (r=0.580**) and remobilization contribution (r=0.564**), therefore the genotypes with high remobilization contribution had high grain yield. Correlation coefficient between remobilization contribution had positive and significant relation with 1000 grain weight (r=0.564**), but positive non-significant relation with other traits (table 7).

Table 7: Correlation coefficient of studied traits in wheat genotypes

	Spikelet No	Grain weight spike^{-1}	Grain spike^{-1}	Grain yield	1000 grain weight	Remobilization contribution
Spike weight	0.596**	0.742**	0.656**	0.271ns	0.458*	0.060ns
Spikelet No		0.674**	0.672**	0.582**	0.480*	0.262ns
Grain weight spike^{-1}			0.625**	0.566**	0.789**	0.287ns
Grain spike^{-1}				0.423ns	0.320ns	0161ns
Grain yield					0.580**	0.564**
1000 grain weight						0.446*

* and ** significant at 1% and 5% probability levels

Cluster analysis of genotypes based on physiological traits

In order to grouping of genotyped based on yield, yield component and remobilization contribution, used minimum Ward method. All genotypes clustered in two groups with 13 and 7 odds (fig 1). Cluster one including genotypes with low grain yield and yield components, low straw weight and high remobilization contribution and low sink limitation. Cluster two including genotypes with high grain yield and yield components, high straw weight and low remobilization contribution and low source limitation as well (table 8). The best liken genotypes to cluster one is C-89-2 and in cluster two, genotypes of C-89-4, C-89-10, C-89-14.

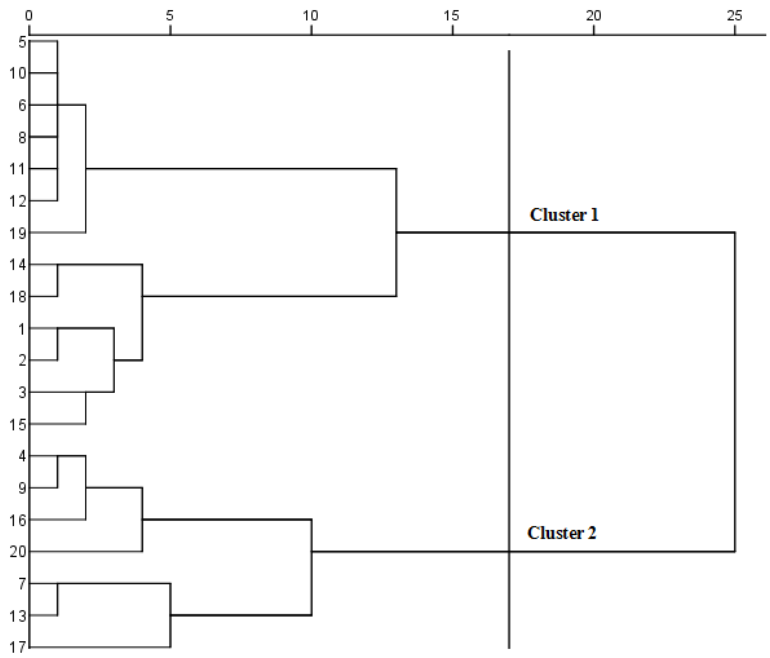

Fig. 1: Dendrogram grouping of wheat genotypes based on minimum Ward method

Table 8: Total means and mean of cluster in some studied traits in wheat genotypes

	Genotypes	Grain yield	1000 grain weight	Grain spike^{-1}	Spikelet No	Straw weight	remobilization contribution	Sink limitation	Source limitation
Cluster 1	1, 2, 3, 5, 6, 8, 10, 11, 12, 14, 15, 18, 19	7890.7	44	33.8	15.3	6851.5	33.1	34.3	16.8
Cluster 2	4, 7, 9, 13, 16, 17, 20	8817.4	47.1	36.3	16.1	8896.1	29	34.6	15.2
Total Mean		8354.1	45.55	35.05	15.7	7873.8	31.05	34.45	16

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