Yield and Some Agronomic Characteristics of Rice (*Oryza sativa* L.) Genotypes in Response to Source-Sink Limitations

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Abstract

To study the effect of source and sink limitation on grain yield and yield components of four genotypes of rice, a field experiment was conducted at Rice Research Station of Tonekabon, Iran during 2013-2014 growing season. The experiment was carried out with a factorial arrangement based on randomized complete block design with four replications. Factors were four rice genotypes (promising line 12, 13, 14 and 18) and four levels of source-sink limitation (control, defoliated all leaves except flag leaf, only flag leaf removal and removal of ⅓ end of panicle). Traits such as grain yield, biological yield, harvest index, tiller number, 1000-grain weight, and panicle fertility were measured. Analysis of variance indicated that effect of genotypes was significant for all of traits except harvest index ($P < 0.01$), while the effect of source-sink limitation was significant for the most traits except harvest index and tiller number. Comparison of means indicated that promising line 12 had the highest grain yield, biologic yield, and 1000-grain weight. Also, among source-sink limitation treatments, the highest values for all traits were recorded for control treatment, while the lowest ones were observed for the removal of ⅓ end of panicle. Results indicated that all genotypes showed both source and sink limitations. Furthermore, by imposing source limitations (particularly defoliated all leaves except flag leaf), increasing in 1000 grain weight of genotypes was more than control and this indicates that there was a source limitation. Generally, this experiment illustrated that yield of the some rice genotypes is sink-limited (Line 12 and 18) and other genotypes (Line 13 and 14) are source-limited and breeding rice with the larger sink or source size in the current genotypes may increased yield potential.

Keywords: rice (*Oryza sativa* L.), grain yield, source-sink limitation, flag leaf

Introduction

Source, sink, and translocation capacity of assimilates play important roles during the formation of grain yield. Grain yield of cereals such as rice and wheat is largely determined by the relationship between the source and sink, and translocation of photosynthates between them. Increased photosynthetic efficiency and greater sink size were seen as approaches to increase yield potential (Yoshida, 1972). However, increased photosynthetic capacity does not often result in higher grain yield, even under favorable conditions (McDonald et al., 1974).

The yield is the result of parameters such as plant growth period, speed, duration and communication of vital processes in plant development. No process alone does provide the key to achieving maximum yield potential. Yield components are not independent of each other and increasing of a component is often reduced other components. Grain yield depends on the number of grains per unit area (sink) and the availability of assimilates (source) to fill these grains. Rice grain filling and ripening are affected by many environmental factors, including water, temperature, radiation, and soil nutritional conditions (Yoshida, 1981). Grain dry matter increase is supported by available assimilates, as defined by C assimilation during the grain filling period plus assimilate re-translocation from straw to grain (Weng et al., 1982).

Better understanding of yield responses to changes in assimilate supply during different phenological phases has been a major advance in crop physiology. Niknejad et al. (2007) showed under the influence of source-sink limitation on rice cultivars, the cultivars including Neda and Tarom produced the highest and the lowest yields, respectively. In the process of assimilate transition; the limited number of vascular bundles is reduced grain fertility. Teimoorian et al. (2009) showed that Japan - India Hybrids, due to limited source have less power of the reservoir activity and therefore, these cultivars produce thinner grains and they have more number of empty, half full grains and unusable carbohydrates. Yang et al. (2002) showed that rice yield is determinate by sink size and the amount of carbohydrates stored in sink at maturity stage. Venkateswarlu (1976) indicated that leaf could determine the degree of plants' performance and the rate of unfilled spikelets. Environmental constraints like low light intensity itself can considerably affect the function of the leaf, resulting in greater proportion of unfilled spikelets or sterility. This suggests that 'source' (leaf) is unable to cater to the requirements of the panicle. Panicle-tailoring studies pointed out that sterility could be reduced if panicle size is reduced. Das and Mukherjee (1991) noted that cutting off the leaves and awns of a dwarf wheat cultivar at the flowering stage reduced dry matter accumulation, spike size, grain weight and grain yield. They illustrated that the proportion of all leaves, flag leaf and awns in the grain yield were 42, 19 and 8.6 percent, respectively. Boshar et al. (1991) reported that the flag leaf in rice has significant effect on grain yield, grains number per panicle, and panicle length. Singh and Ghosh (1981) stated that flag leaves play a major role in synthesis and translocation of photo-assimilates to the rice seeds, affecting grain yield. Removal of the rice flag leaf at any stage after panicle emergence was reported to cause significant reduction in grain yield.

Grain yield is a complex trait and influenced by many factors. So, to enhance grain yield production in rice, determining factors should be identified (Acreche and Slafer, 2006). For breeders, determination of source and sink limitation in grain yield production of rice is very important. So far, despite the importance of source and sink limitation in grain yield production of rice, there has been little discussion about them especially in different rice cultivars in Iran.

The objectives of this research were to determine the roles of source and sink limitations on formation of grain yield and its components in different improved rice cultivars.

Materials and Methods

Experimental Design, Plant Culture and Management

Field experiment was conducted on a lowland rice field at the Rice Research Station of Tonekabon (36°51' N, 50°46' E; -21 m above sea level), Iran, in 2013. Soil properties were 2.4% organic matter content, 30% clay, 45% silt, 25% sand, and pH=6.9. Experiment was carried out with a factorial arrangement based on randomized complete block design with four replications. Studied factors were four rice genotypes (promising line 12, 13, 14 and 18) and four levels of source-sink limitation (control, defoliated all leaves except flag leaf, only flag leaf removal, and removal of ⅓ end of panicle). The name of genotypes and parents of these genotypes are given in Table 1.

Individual plots were 2 m wide by 4 m long and genotypes were transplanted on 16 May 2013, with planting distance of 25×25 cm^2. Total fertilizer applied was 200 kg N ha^{-1}, 100 kg P ha^{-1} and 150 kg K ha^{-1} with split application broadcast at transplanting stage (30% N and 100% P.K.), at panicle initiation (35% N), and 5 days before flowering (35% N). Moreover, during the growing season, all unwanted weeds were hand weeded. At the beginning of anthesis stage, 20 plants from the central rows of each plot were tagged and levels of sink and source limitation treatments were established.

Table 1 Genotype name and parents of 4 rice promising lines.

Genotypes	Parents		
	♂		♀
Line 12	Number 39 of IR 67015-22-6-2 (A37632)	×	Amol 3 × Number 3
Line 13	Number 1 of Shiroudi	×	Mousa Tarom
Line 14	Number 19 of IR 67015-22-6-2 (A37632)	×	Amol 3 × Number 3
Line 18	Number 27 of IR 67015-22-6-2 (A37632)	×	Amol 3 × Number 3

Plant Sampling

At maturity, for determining the final grain yield, 16 hills (1 m^2) were harvested by hand-cutting from each plot and adjusted to 14% moisture. For each plot, ten plants randomly selected and yield components and agronomic traits were measured. Rice aboveground biomass from each plot was placed in separate paper bags, dried at 72°C for 48 h, and weighed.

Harvest index (HI) calculated from the following formula: HI = (Economic yield×100)/ Biological yield

Panicle fertility computed from the following formula: (Number of filled grains ×100)/Total number of grain per panicle

Also, percentage of source limitations calculated from the following formula: Panicle fertility = (Grains weight at limitation treatment ×100)/ Grains weight at control

Statistical Analyses

All data were subjected to analysis of variance (ANOVA), and means were compared using Fisher's protected LSD test at α=0.05. All statistical analyses were conducted by using SAS (SAS Institute, Inc, 2002).

Results and Discussion

Results and discussion

Analysis of variance showed that genotypes have significant effect ($P< 0.01$) on all traits except harvest index (HI) (Table 2). Moreover, there were significant effects ($P< 0.01$) of source-sink limitation on all rice traits except HI and tiller number. The interactions between genotypes and source-sink limitation were significant for grain yield, biological yield and 1000-grain weight. Harvest index was not influenced by the presence of source-sink limitation treatments (Table 2). This is indicated that the percentage reductions of grain yield and biomass by source-sink limitation were similar.

The grain yield was significantly affected by different genotypes at various levels of sink-source limitation (Figure 1). The highest and the lowest grain yield were observed for line 12 (8202.5 kg ha^{-1}) and line 18 (3229.5 kg ha^{-1}), respectively. Removal of ⅓ end of panicle at anthesis stage resulted in a decrease of 58.34 percent in grain yield at line 18, which had the greatest yield reduction at all levels of sink-source limitation in comparison with other genotypes. Also, the maximum yield reduction belonged to line 14 at defoliated all leaves except flag leaf line (35.32 %) (Figure 1). The comparison between control and defoliated plants indicated that cultivars differed in the ability to remobilize reserves from the stems to the grains. Such differences in the response to availability of photoassimilates seem to be the consequence of different patterns of photoassimilate partitioning between cultivars with varying source and sink ratios (Evans and Wardlaw, 1970). Some researchers reported that role of awn photosynthesis on the grain yield is more than photosynthesis of leaves (Maydup et al., 2010). Birsin (2005) reported that the leaves especially flag leaf is a production source for photosynthesis and it is the most influential factors on the growth of the seeds. Also, effects of various levels of sink-source limitation on biological yield at different rice genotypes were similar with grain yield. Line 12 (15072 kg ha^{-1}) and line 18 (6118 kg ha^{-1}) had the highest and lowest biological yield, respectively (Figure 2).

Table 2 Analysis of variance for yield and yield components of rice as affected by genotype and level of sink and source limitation

Source of variation	df	Mean square (MS)					
		Grain yield	Biological yield	Harvest index	Tiller number	1000-grain weights	Panicle fertility
Rep.	3	402341.79	2008350.6	3.49	14.13	2.74	32.31
Genotype (G)	3	10574459.81**	25950354**	37.63ns	146.04**	48.12**	347.16**
Source-sink limitation (S)	3	19251467.97**	52922210**	33.51ns	27.13ns	2.63**	303.41**
G×S	9	3832413.41**	11626125.9**	22.93ns	13.78ns	3.59**	65.53ns
Error	45	854938.6	2308479.2	14.78	11.03	0.92	32.34
CV (%)		15.32	13.81	7.03	15.44	3.17	7.67

*, ** significant at the 5% and 1% levels of probability, respectively; ns indicates none significant

The highest 1000-grain weight was obtained at removal of ⅓ end of panicle in line 12 (33.25 g) and line 13 (28.03 g) had the lowest decrease of 1000-grain weight at defoliated all leaves except flag leaf (Figure 3). The higher seed weight in the removal of ⅓ end of panicle can attributed to the less grain number and greater assimilate availability for remained grain for this treatment. In other words, sink limitation in the removal of ⅓ end of panicle caused that the available sinks reach to their maximum weight. Duggan and Fowler (2006) observed that removal of the lower spikelets of wheat spike caused that the grain weight of upper parts of spike increased up to 22 percent. Ohsugi (2004) reported that rice grains showed different patterns of grain filling depending on their position within a panicle.

The highest and the lowest panicle number per plant were recorded for the line 18 (25.31) and line 12, respectively (Figure 4). Sink-source limitation had no significant effect on panicle number. As Sink-source limitation factors were exerted after flowering stage, it is obvious that panicle number was not influence by this factor, because rice plants complete tillering before flowering stage. The maximum and minimum levels of panicle fertility were recorded for line 18 (78.99 %) and line 13 (68.12 %), respectively (Figure 5). In different source-sink limitation levels, the most and the least panicle fertility belonged to control (78.4 %) and defoliated all leaves except flag leaf (68.49 %), respectively. Ueda et al. (1998) reported that fertility percentage of 77 rice cultivars at four various collations were between 60 to 90 percent. Ashraf et al. (1994) showed that reduction of assimilate capacity allocation from source to sink can be another agent for fertility limitation of grains.

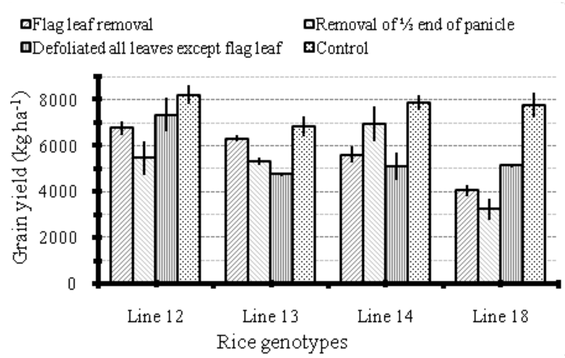

Figure 1 Changes in grain yield of rice genotypes under different levels of source and sink limitation

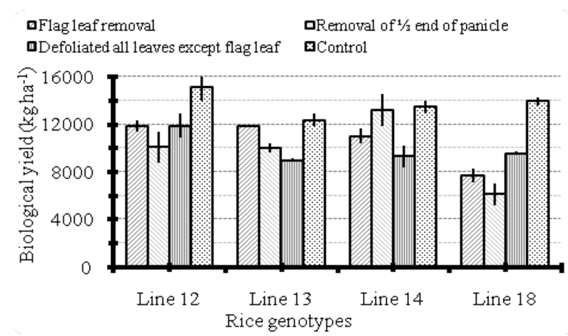

Figure 2 Changes in biological yield of rice genotypes under different levels of source and sink limitation

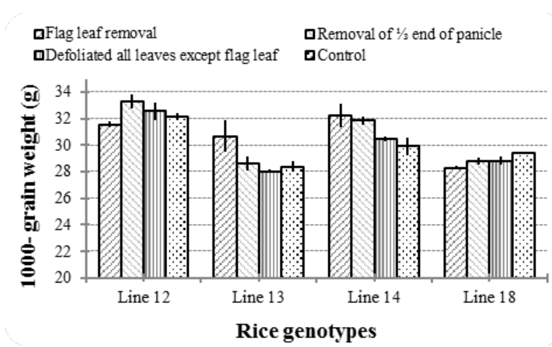

Figure 3 Changes in 1000-grain weight of rice genotypes under different levels of source and sink limitation

Based on Table 3, the most source restriction belonged to line 18 when ⅓ end of panicle was removed (-58.34 %), and the lowest one was recorded for line 13 when flag leaf was removed (-7.51 %). It seems that flag leaf of line 13 has less impact on the grain yield and transfer of assimilates than other genotypes. Different responses of rice genotypes to source limitation can be attributed to genetic diversity, the effects of feedback mechanism, excitability effect on plant and the time and intensity of the environmental condition changes (Ma et al., 1990). Rao (1991) found that flag leaf removal has the most effect on grain yield and cutting off two lower leaves and cutting off forth leaf have negative and little effect on grain yield, respectively.

Conclusions

In conclusion, the pattern of partitioning of assimilate accumulation observed in this research suggests a diverse sink and source relationship in different rice genotypes. Results obtained in this experiment showed that by applying sink-source limitations, the yield and the yield components decreased. Line 12 had the highest grain yield among tested genotype. To achieve the maximum economical yield in these genotypes, it should be considered any form of source limitation such as the sheath-burning disease and environmental stresses like drought that they can lead to the extreme yield reduction of these genotypes. However, protecting the leaves through spraying nutrients or eradicating the pests and diseases can improve the yield.

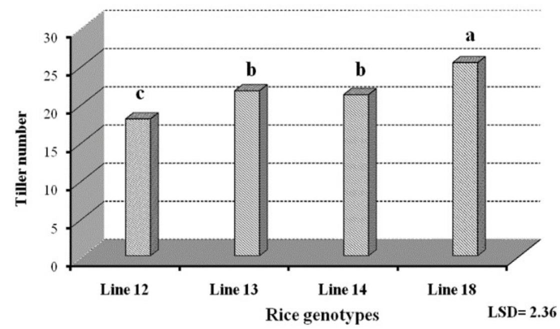

Figure 4 Tiller number per plant for different rice genotypes

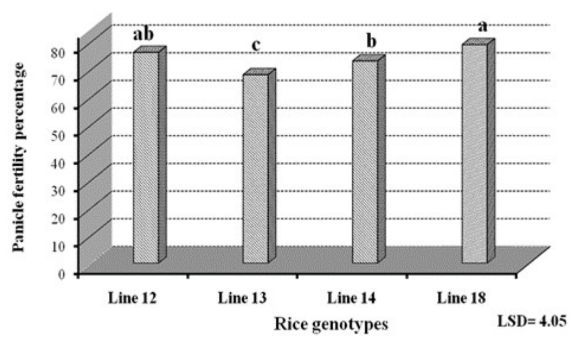

Figure 5 Panicle fertility percentage in different rice genotypes

Table 3 Percentage of source limitations in four rice genotypes

Genotype	Source-sink limitations	Percentage of source limitations
Line 12	Flag leaf removal	-17.6
	Removal of ⅓ end of panicle	-33.45
	Defoliated all leaves except flag leaf	-10.58
Line 13	Flag leaf removal	-7.51
	Removal of ⅓ end of panicle	-22.26
	Defoliated all leaves except flag leaf	-30.38
Line 14	Flag leaf removal	-28.64
	Removal of ⅓ end of panicle	-11.5
	Defoliated all leaves except flag leaf	-35.32
Line 18	Flag leaf removal	-47.88
	Removal of ⅓ end of panicle	-58.34
	Defoliated all leaves except flag leaf	-33.71

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