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Research Paper

Effect of varieties and nitrogen levels on growth indices of malt barley (*Hordeum vulgare*) under saline water irrigation

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ABSTRACT

A field experiment was conducted during the winter (*rabi*)season of 2017–18 and 2018–19 at the Chaudhary Charan Singh Haryana Agricultural University, Hisar, to study the effect of saline water irrigation on growth indices in 4 varieties ('BH 902', 'BH 946', 'BH 885' and 'DWRB 101') of barley (*Hordeum vulgare* L.) at different nitrogen levels (0, 30, 60 and 90 kg/ha). The results showed that, during early growth period both 6-row barley varieties 'BH 902' and 'BH 946' recorded significantly higher crop-growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weigth (SLW) and leaf-area duration (LAD) than both 2-row barley varieties 'BH 885' and 'DWRB 101', whereas 'BH 885' and 'DWRB 101' varieties attained higher values of RGR and NAR after 90 days after sowing (DAS). The CGR and LAD recorded maximum values between 61 and 90 DAS, while RGR and NAR showed the highest values up to 30 DAS irrespective of varieties and nitrogen levels. Application of 90 kg N/ha significantly enhanced the CGR up to 90 DAS, RGR up to 30 DAS and LAD up to 120 DAS, while NAR values were significantly increased up to 60 DAS with 30 kg N/ha and SLW up to 90 DAS with 60 kg N/ha. The RGR, NAR and SLW were significantly decreased with the application of different nitrogen levels between 91 and 120 DAS as compared to the control. The variety 'BH 946' gave the highest grain yield of 5.15 t/ha, being 5.1, 7.3 and 14.7% higher than 'DWRB 101', 'BH 902' and 'BH 885', respectively. Different varieties responded to N application only up to 60 kg/ha. Grain yield of barley was positively correlated with CGR, SLW and LAD but negatively with RGR.

Key words: Barley varieties, CGR, Grain yield, LAD, NAR, Nitrogen, RGR, SLW

Barley is considered as poor man's crop because of its low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands. Farmers prefer barley where wheat cannot be grown due to limitations of inputs, insufficient irrigation water and environment unsuitable for other crops. Barley was grown on an area 0.02 million hectares with the production of 0.73 million tonnes and productivity of 3,650 kg/ha in Haryana (Indiastat.com 2019). Due to uncertainty of rainfall and scarcity of water, farmers of Haryana often irrigate the crops with poor-quality water and this situation is likely to become more alarming with the depleting water resources. Thus, there is need to find out the ways to use poor quality water for crop production. The important use of barley throughout the world is as malt for manufacturing beverages, malt enriched food products, beer and whiskey production. Barley is a rich source of nutrients like protein, vitamin B, niacin, dietary minerals and dietary fibre and forms a staple food for many people in India. Many dishes like *chapati, sattu* (in summers because of its cooling effects on human body) and *missi roti* prepared from barley flour are still highly popular in India.

The barley varieties generally differ in their yield potential and malt quality parameters. Kassie and Tesfaye (2019) reported 17.7% higher grain yield in variety 'Miscal 21' than 'Holker'. Variety 'Miscal 21' also recorded higher protein content in grain, while hectolitre weight was more in variety 'Holker'. The research findings indicated that, some varieties may have very high yield potential but have poor malting characteristics, while other varieties may exhibit good malting characteristics but have poor yield potential. Similarly, some varieties responded to higher nitrogen levels but other varieties responded to lower nitrogen levels. Hence there is a need to evaluate the varieties with matching nitrogen levels that give good yield as well as malting characteristics. However, information on the effect of nitrogen levels on grain yield and malt quality of different barley varieties particularly under saline water

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irrigation is not available in India. Keeping the above aspects in view, the present study was undertaken to find suitable variety and optimize N for barley production.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2017–18 and 2018–19 at the Chaudhary Charan Singh Haryana Agricultural University, Hisar, which is situated in semi-arid, sub-tropics at 29º 8´N, 75º 70´E at 215.2 m above mean sea-level, Haryana. It has a semi-arid, sub-tropical climate with hot and dry desiccating winds and frequent dust storms during summer, severe cold during the winter and warm humid conditions during the monsoon months. The average maximum and minimum temperature shows a wide degree of fluctuations during summer and winter months. The average annual rainfall is 450 mm, out of which 70–80% is received during July–September and the rest in winter and spring seasons. Total rainfall of 15.9 mm and 28.6 mm and pan evaporation of 47.1 mm and 41.8 mm was recorded during 2017–18 and 2018–19 respectively. The soil was sandy loam with soil *p*H of 8.3, available nitrogen 175.0 kg/ha, phosphorus 17.0 kg/ha and potassium 320.0 kg/ha. The experiment was carried out in a split-plot design, keeping 4 varieties ('BH 902', 'BH 946', 'BH 885' and 'DWRB 101') in main plots and 4 nitrogen levels (0, 30, 60 and 90 kg/ha) in subplots with 4 replications. The crop was sown on 22 November 2017 and 26 November 2018 by *pora* method at row spacing of 22 cm using 90 kg/ha seed rate. Half dose of nitrogen as per treatment and full dose of phosphorus and potassium were applied at sowing in the form of urea, single super phosphate and muriate of potash fertilizers respectively. The remaining nitrogen was top-dressed as per treatment after the first irrigation. The crop was irrigated twice during each growing season with saline water having EC_{iw} 8.0 dS/m, *p*H 7.5 and sodium adsorption ratio (SAR) of 15.2 me/litre. Dry-matter accumulation data recorded at 30, 60, 90 and 120 days after sowing (DAS) were used to calculate crop-growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW) and leaf area duration (LAD).

The crop was harvested manually on 6 April 2018 and 8 April 2019. The data were statistically analyzed by using the technique of analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Crop-growth rate

Crop-growth rate (CGR) indicates at which rate the crop is growing. The data given in Table 1 showed that CGR continuously increased up to 90 days after sowing (DAS) and thereafter decreased in varieties 'BH 902', 'BH 946' and 'DWRB 101', but continued to increase up to 120 DAS in variety 'BH 885'. During 0–30 DAS period, 'BH 902' exhibited the maximum CGR (1.13 g/m^2/day) which was statistically similar to 'BH 946' but was significantly higher than 'BH 885' and 'DWRB 101'. At 31–60 DAS and 61–91 DAS stages, significant higher CGR was recorded by variety 'BH 946' which was followed by 'BH 902', 'DWRB 101' and lowest in 'BH 885', the latter 2 varieties also differed significantly. Different varieties did not significantly influence the CGR during 91–120 DAS, although variety 'BH 885' recorded numerically higher values of CGR. The variation in CGR among different varieties may be attributed to variable production of dry matter during respective time intervals that directly linked with genetic makeup of the varieties.

The CGR followed an increasing trend with the increase in N doses from 0 to 90 kg/ha. Application of 90 kg N/ha significantly enhanced CGR during 0–30 DAS (1.20 g/m^2/day), 31–60 DAS (10.26 g/m^2/day) and 61–90 DAS (13.26 g/m^2/day) as compared to the control, 30 and 60 kg N/ha. Use of 30 and 60 kg N/ha also had significant effect on CGR as compared to the control. However, during 91–120 DAS period, both 60 and 90 kg N/ha remained statistically similar and recorded significantly more CGR than the control and 30 kg N/ha; the latter 2 remained statistically similar with each other. Increase in the CGR with application of 90 kg N/ha was owing to increase in plant height and dry-matter production under the highest level of nitrogen. Reddy and Singh (2018) observed that, 75 kg N/ha significantly enhanced the crop growth rate in comparison to 45 and 60 kg N/ha but was statistically similar with 90 kg N/ha.

Relative growth rate

The relative RGR is a measure to determine the speed of plant growth. It expresses the increase in dry weight per unit dry weight already present. The data presented in Table 1 showed that, RGR varied significantly among different treatments at all the growth stages. The data revealed that, RGR attained the maximum values during 0–30 DAS and thereafter it showed the decreasing trend up to 120 DAS. During 0–30 DAS period, variety 'BH 902' revealed the maximum RGR (50.8 mg/g/day) which was significantly higher than the 'BH 885' and 'DWRB 101' but statistically at par with variety 'BH 946'. During 31–60 DAS period, variety 'BH 946' attained significantly higher 'RGR than 'BH 902', 'DWRB 101' and 'BH 885' (Table 1). However, during 61–90 DAS and 91–120 DAS, variety 'BH 885' attained significantly higher values of RGR (10.9 and 7.2 mg/g/ day) in comparison to the other varieties. The difference in RGR among different varieties was due to variation in their genotypic makeup.

Nitrogen levels significantly affected the RGR at all the growth stages. The pooled data revealed that, during 0–30

Table 1. Effect of different varieties and nitrogen levels on periodical changes in crop-growth rate, relative growth rate and net assimilation rate in barley (pooled data of 2 years)

Treatment	Crop growth rate ($g/m^2/day$)				Relative growth rate (mg/g/day)				Net assimilation rate ($mg/m^2/day$)			
	0–30 DAS	31–60 DAS	61–90 DAS	91–120 DAS	0–30 DAS	31–60 DAS	61–90 DAS	91–120 DAS	0–30 DAS	31–60 DAS	61–90 DAS	91–120 DAS
Varieties												
‘BH 902’	1.13	9.28	12.31	10.86	50.8	32.1	11.3	5.7	0.906	0.368	0.195	0.192
‘BH 946’	1.10	9.97	13.08	11.18	50.4	33.4	11.3	5.6	0.898	0.398	0.204	0.193
‘BH 885’	0.96	7.43	9.71	11.19	48.5	31.4	10.9	7.2	0.904	0.343	0.178	0.233
‘DWRB 101’	1.04	8.84	11.83	10.37	49.6	32.5	11.4	5.8	0.918	0.380	0.199	0.197
SEm±	0.01	0.11	0.10	0.28	0.1	0.2	0.1	0.1	0.001	0.001	0.001	0.001
CD (P=0.05)	0.04	0.33	0.29	NS	0.4	0.6	0.3	0.4	NS	0.017	0.006	0.013
Nitrogen (kg/ha)												
Control	0.86	6.14	8.74	10.19	46.9	30.4	11.7	7.4	0.847	0.346	0.199	0.254
30	1.03	9.24	12.08	10.34	49.6	33.4	11.1	5.5	0.913	0.391	0.198	0.187
60	1.14	9.88	12.87	11.41	51.1	32.9	11.1	5.7	0.933	0.377	0.191	0.189
90	1.20	10.26	13.26	11.67	51.8	32.8	11.0	5.6	0.934	0.375	0.188	0.184
SEm±	0.01	0.05	0.05	0.15	0.1	0.1	0.1	0.1	0.001	0.002	0.001	0.001
CD (P=0.05)	0.02	0.13	0.13	0.45	0.3	0.4	0.2	0.2	0.026	0.017	0.003	0.013

DAS, Days after sowing

DAS, 90 kg N/ha recorded significantly more RGR (51.8 mg/g/day) than 60 kg N/ha, 30 kg N/ha and control (Table 1). However, during 31–60 DAS period, nitrogen application at 60 and 90 kg/ha recorded statistically similar and significantly higher values of RGR than 30 kg N/ha and the control treatment. While during 61–90 and 91–120 DAS period, the maximum RGR was observed under the control (11.7 and 7.4 mg/g/day) which was significantly higher in comparison to 30, 60 and 90 kg N/ha. However, Reddy and Singh (2018) found that, 75 kg N/ha significantly improved RGR in comparison to 45 and 60 kg N/ha but was statistically similar with 90 kg N/ha.

Net assimilation rate

Net assimilation rate (NAR) is the increase in dry weight of plant per unit leaf area per unit time. The data on NAR at different growth stages given in Table 1 showed that, different varieties recorded statistically similar net assimilation rate during 0–30 DAS and the values ranged between 0.898 and 0.918 $mg/m^2/day$. The pooled data showed that, during 31–60 DAS and 61–90 DAS, variety ‘BH 946’ recorded the maximum NAR (0.398 and 0.204 $mg/m^2/day$), being significantly higher than ‘BH 902’ and ‘BH 885’ but was statistically similar with the variety ‘DWRB 101’. During 91–120 DAS, variety ‘BH 885’ attained significantly higher NAR (0.233 $mg/m^2/day$) than the other varieties which were statistically similar among each other. This was owing to the fact that genetic differences exist among different genotypes for growth and development parameters that caused variation in DMA and LAI and ultimately influenced the NAR.

Nitrogen levels significantly influenced the NAR at all the growth stages. During 0–30 and 31–60 DAS, nitrogen application at 30, 60 and 90 kg/ha recorded statistically similar but significantly higher values of NAR than the control, whereas during 61–90 DAS period, the control and 30 kg N/ha attained statistically similar but significantly higher NAR than 60 and 90 kg N/ha. However, at 91–120 DAS the maximum NAR was recorded under control (0.257 and 0.252 $mg/m^2/day$) which was significantly higher than all the other N levels during both the years. Thus the data showed that, nitrogen application decreased the NAR after 90 DAS. The interaction effect with respect to NAR was not significant during both the years.

Specific leaf weight

The data on specific leaf weight (SLW) at various stages given in Table 2 indicated that, all the varieties remained statistically at par at 30 DAS and did not exhibit any significant improvement in SLW. At 60 and 90 DAS, the pooled data showed that the maximum SLW (0.0032 and 0.0044 cm^2/g) was recorded in ‘BH 946’ which was significantly higher to all the other varieties. The lowest SLW was observed in variety 'BH 885'. The results indicated that, at 120 DAS the maximum SLW (0.0107 cm^2/g) was attained by variety 'BH 885' which remained statistically at par with 'DWRB 101' and showed significant improvement over 'BH 902' and 'BH 946'. This was attributed to the variation in DMA and leaf-area index (LAI) among different genotypes that ultimately influenced the SLW.

Nitrogen levels significantly affected SLW at all stages of observations. All nitrogen levels exhibited significant improvement in SLW up to 90 DAS over the control. The pooled data showed that, 90 kg N/ha resulted in highest values of SLW at 30 DAS (0.0061 cm^2/g), 60 DAS (0.0030 cm^2/g) and 90 DAS (0.0040 cm^2/g) and showed its significant superiority over the control, but it was statistically similar with 30 and 60 kg N/ha. However at 120 DAS, the control treatment showed significant improvement in SLW over 30, 60 and 90 kg N/ha. This was attributed to the variation in dry-matter production and LAI at various growth stages.

Leaf-area duration

Leaf-area duration (LAD) is the integration of leaf-area index over time. The data on LAD are presented in Table 2 indicated that, LAD increased sharply from the initial stage and attained its highest values between 61 to 90 DAS and declined thereafter. The pooled data of two years study showed that, among different varieties, the LAD ranged between 11.4 and 13.7 days, 55.9 and 65.0 days, 89.0 and 106.0 days and 44.9 and 53.4 days from 0–30 DAS, 31–60 DAS, 61–90 DAS and 91–120 DAS respectively. Variety 'BH 902' recorded the maximum LAD at 30 DAS which was significantly higher than 'BH 885' and 'DWRB 101' but was statistically at par with variety 'BH 946'. Varieties 'BH 885' and 'DWRB 101' attained statistically similar LAD at this stage. At 31–60 DAS, 61–90 DAS and 91–120 DAS growth the stages, the maximum LAD was attained by variety 'BH 946' which was statistically similar with 'BH 902' and significantly higher than 'BH 885' and 'DWRB 101', the latter 2 varieties also differed significantly. Variety 'BH 885' exhibited the lowest values of LAD. The difference in LAD among the barley varieties was attributed to their genetic makeup and the prevailing environmental conditions for better growth.

Nitrogen levels significantly affected LAD of barley at all the growth stages. An increase in dose of nitrogen significantly enhanced the LAD up to 90 kg N/ha at all the stages of observation. During 61–90 DAS stage, 90 kg N/ha resulted in 6.6, 16.3 and 40.3 days higher LAD than 60 kg N/ha, 30 kg N/ha and the control, respectively. Higher leaf-area duration with 90 kg N/ha was attributed to higher leaf-area index at all the growth stages. Javaheri *et al.* (2014) also observed positive effect of nitrogen on leaf-area duration owing to higher LAI and green area for more light interception and photosynthesis that leads to higher accumulation and translocation of photo-assimilates and ultimately resulting in higher grain yield.

Grain yield

The grain yield is a principle criterion for evaluating efficiency of various treatments because ultimate effects of

Table 2. Effect of different varieties and nitrogen levels on periodical changes in specific leaf weight and leaf-area duration in barley (pooled data of 2 years)

Treatment	Specific leaf weight (9/cm²)				Leaf-area duration (days)				Grain yield (t/ha)
	30 DAS	60 DAS	90 DAS	120 DAS	0–30 DAS	31–60 DAS	61–90 DAS	91–120 DAS	
Varieties									
'BH 902'	0.0059	0.0029	0.0041	0.0101	13.7	64.7	104.0	52.2	4.77
'BH 946'	0.0059	0.0032	0.0044	0.0104	13.4	65.0	106.0	53.4	5.15
'BH 885'	0.0061	0.0025	0.0029	0.0107	11.4	55.9	89.0	44.9	4.39
'DWRB 101'	0.0061	0.0029	0.0041	0.0105	12.3	60.6	98.2	48.3	4.89
SEm±	0.0001	0.0001	0.0001	0.0001	0.3	0.5	0.7	0.4	0.07
CD (P=0.05)	NS	0.0001	0.0001	0.0003	0.9	1.6	2.2	1.3	0.27
Nitrogen (kg/ha)									
Control	0.0057	0.0028	0.0037	0.0114	10.8	42.2	74.8	36.8	3.88
30	0.0060	0.0029	0.0039	0.0103	12.2	62.4	98.8	49.4	4.87
60	0.0062	0.0030	0.0040	0.0102	13.5	69.5	108.5	55.3	5.21
90	0.0062	0.0030	0.0040	0.0101	14.2	72.1	115.1	57.3	5.24
SEm±	0.0001	0.0001	0.0001	0.0001	0.1	0.4	0.4	0.2	0.02
CD (P=0.05)	0.0002	0.0001	0.0001	0.0002	0.5	0.4	0.3	0.7	0.07

DAS, Days after sowing

experimental variables are reflected on final crop yield. The data showed that the maximum grain yield was given by variety 'BH 946' and it was statistically similar with variety 'DWRB 101' but significantly higher than variety 'BH 902' and 'BH 885'. Variety 'DWRB 101' also gave significantly higher grain yield than 'BH 885' being statistically similar to 'BH 902'. The lowest yield was recorded in 'BH 885'. Variety 'BH 946' gave the highest yield of 5.15 t/ha being 5.1, 7.3 and 14.7% higher than 'DWRB 101', 'BH 902' and 'BH 885' respectively (Kaur and Satyavan, 2020). It was attributed to its better genetic growth parameters which intercepted higher solar radiation and leads to more photosynthesis that positively affected the translocation of assimilated photosynthates from source to sink and resulted in higher grain yield. Kassie and Tesfaye (2019) reported that, variety 'Miscal 21' recorded 17.7% more grain yield than variety 'Holker'. Saha *et al.* (2018) also reported varietal differences for yield. Nitrogen levels also showed significant variation with respect to grain yield of barley. Each incremental dose of 30 kg N/ha resulted significantly higher yield up to 60 kg N/ha and further enhancing nitrogen level up to 90 kg/ha did not significantly affect the grain yield. Our results support the findings of Pradhan *et al.* (2018), who also reported that grain yield was significantly increased with increasing nitrogen levels. Contrary to the above findings, Terefe *et al.* (2018) observed that, grain yield of malt barley improved with increasing N level up to 36 kg N/ha and decreased thereafter at 54 kg N/ha.

Growth indices correlation with yield

The data showed that, grain yield of malt barley was positively correlated with CGR, specific leaf weight and leaf-area duration (Figs. 1, 4, 5) but negatively with RGR (Fig. 2). The NAR did not show any specific correlation with grain yield (Fig. 3).

It may be concluded that crop-growth rate (CGR) and leaf-area duration (LAD) recorded maximum values between 61–90 DAS while relative growth rate (RGR) and net assimilation rate (NAR) recorded highest values up to 30 DAS irrespective of varieties and nitrogen levels.

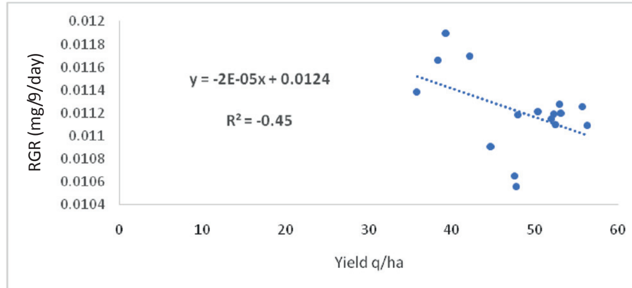

Fig. 2. Correlation between relative growth rate (61–90 days after sowing) and grain yield of barley

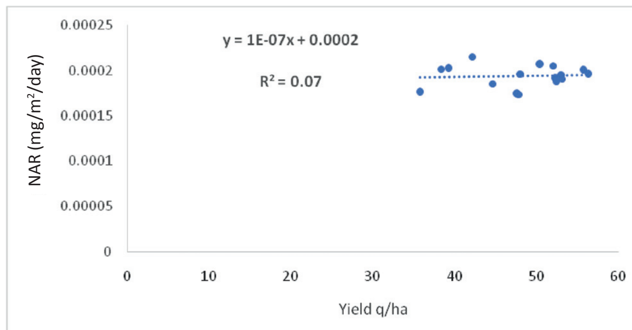

Fig. 3. Correlation between net assimilation rate (61–90 days after sowing) and grain yield of barley

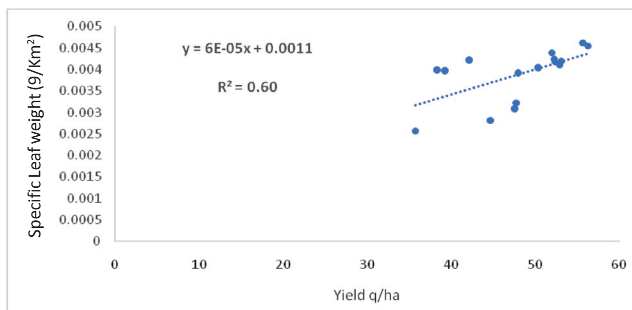

Fig. 4. Correlation between specific leaf weight (61–90 days after sowing) and grain yield of barley

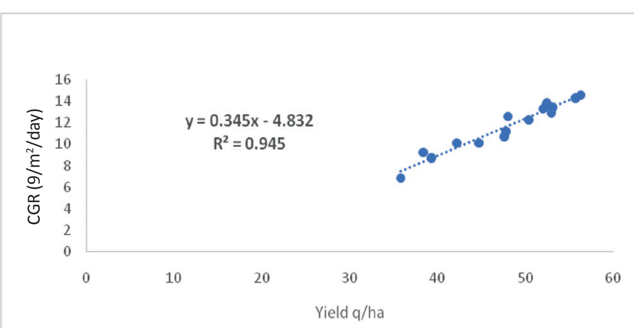

Fig. 1. Correlation between crop-growth rate (61–90 days after sowing) and grain yield of barley

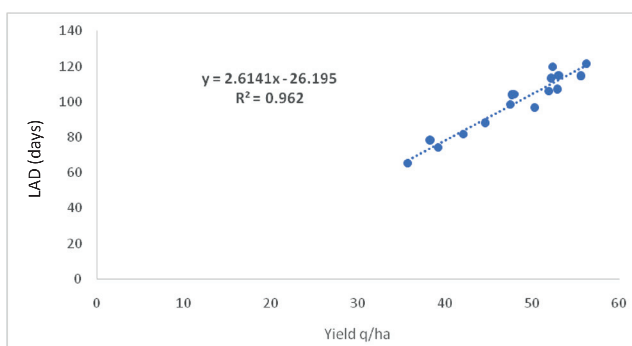

Fig. 5. Correlation between leaf-area duration (90 days after sowing) and grain yield of barley

Application of 90 kg N/ha significantly enhanced the CGR up to 90 DAS, RGR up to 30 DAS and leaf-area duration LAD up to 120 DAS, while NAR values were significantly increased up to 60 DAS with 30 kg N/ha and specific leaf weight (SLW) up to 90 DAS with 60 kg N/ha. Grain yield of barley was positively correlated with crop-growth rate (CGR), specific leaf weight (SLW) and leaf-area duration (LAD) but negatively correlated with RGR.

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