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Dry matter accumulation, nutrient content and uptake of two rowed malt barley as influenced by agronomic practices

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Abstract
A field trial was conducted during the *rabi* season of 2014-15 at Research Farm area of CCS Haryana Agricultural University, Hisar. In the study two seed rate (87.5 and 100 kg ha^{-1}) and three spacing (18, 20 and 22 cm) were used in main plots and four nitrogen levels (60, 75, 90 and 105 kg ha^{-1}) in sub plots with three replication under split plot experimental design. The dry matter accumulation as well as grain yield improved significantly with the use of 100 kg seed rate as compared to 87.5 kg ha^{-1}. The nutrients content were statistically similar under both seed rates. However, the NPK uptake of grain as well as total uptake of N and P increased significantly with 100 kg seed rate as compared to 87.5 kg ha^{-1}. The dry matter accumulation was significantly higher under 18 cm row spacing in comparison to both 20 and 22 cm spacing. Row spacing had no significant effect on NPK content of grain and straw of malt barley. However, total NPK uptake and grain yield with 18 cm row spacing was significantly higher than 22 cm but was at par to 20 cm. Dry matter accumulation, N content and total NPK uptake increased significantly up to 90 kg N ha^{-1}. Total NPK uptake was highly and positively correlated with dry matter accumulation having determination factor of 0.982, 0.989 and 0.989, respectively. Similarly, the dry matter accumulation was positively correlated with quality parameters *viz.* husk and protein content whereas it was negatively correlated with starch and malt content.

Keywords: Two rowed barley, seed rate, row spacing, nitrogen levels, dry matter accumulation, NPK uptake, quality parameters, correlation

Introduction

Barley is the major cereal crop, cultivated in different types of environments ranging from the desert of the Middle East to the high elevation of Himalayas (Hayes *et al.*, 2003 and Hingonia *et al.*, 2016) [8, 9]. It is a multipurpose crop grown for feed, fodder and malt. It occupies fourth position in total cereal production in the world after wheat, rice, and maize (Pal *et al.*, 2012) [23]. It is more productive under adverse environments than other cereals. In India, it is cultivated on about 5.9 lakhs ha area with production of 17.2 lakhs tons and productivity of 2.9 metric ton per hectare (Anonymous 2020-21) [3]. The agronomic practices like seed rate and row spacing play a key role for better growth, dry matter accumulation (Singh *et al.*, 1978; O'Donovan *et al.*, 2011) [31, 21], yield (McKenzie *et al.*, 2011; Kumar *et al.*, 2013) [17, 14] and higher nutrient uptake (Kumar *et al.*, 2006) [13] of barley. With the growing demand of malt barley in India, development of varieties with higher malt content is a focused area. These practices for malt barley may be different from its grain crop. Nitrogen is commonly the most limiting nutrient for crop production in the majority of the world's agricultural areas. It is the key constituent of amino acids, which is a precursor to protein. Thus, good nitrogen management strategies are required for increasing economic returns of the farmers. The improved nitrogen application have been reported to remarkably influence dry matter production (Meena *et al.*, 2012; Singh *et al.*, 2013) [18, 30], yields (Paramjit *et al.*, 2001; O'Donovan *et al.*, 2015; Kakraliya *et al.*, 2017; 2017a,) [25, 22, 11, 12], quality (Sainju *et al.*, 2013; Valkama *et al.*, 2013; O'Donovan *et al.*, 2015) [27, 35, 22] and nutrient content and uptake (Taalab *et al.*, 2015) [33] in barley crop.

The studies on uptake of nutrients by the crop is of great interest as it helps in optimizing the nutrient schedule to enhance nutrient use efficiency as well as to obtain higher economic returns with increased yield and reduced cost of crop production. The work undertaken on these aspects in two rowed barley variety BH 885 is very meagre.

Therefore, keeping this in view the present experiment was conducted to study the effect of seed rate, row spacing and nitrogen levels on dry matter accumulation, yield, nutrient content and uptake and to work out the relationship of dry matter with total nutrient uptake and quality parameters of malt barley.

Materials and Methods

The field study was undertaken at Research Farm, Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India), during *rabi* 2014-15. The farm is situated at 29°10' N latitude and 75° 46' E longitude at an elevation of 215.2 m above mean sea level. During the crop-growing period, the mean weekly maximum temperature ranged between 13.8 to 32.4 ºC, minimum temperature 4.0 to 17.6 ºC and rainfall was 225.8 mm and total pan evaporation 298.9 mm. The soil was sandy loam in texture, slightly alkaline in reaction (pH 8.3), low in organic carbon (0.32%) and available nitrogen (135 kg N ha^{-1}), medium in available phosphorus (17 kg P ha^{-1}) and high in available potassium (334 kg K ha^{-1}). The experiment was carried out in split plot design with three replications by assigning the combination of two seed rates (87.5 and 100 kg ha^{-1}) and three spacings (18, 20 and 22 cm) in main plots and four nitrogen levels (60, 75, 90 and 105 kg N ha^{-1}) in sub plots. The sowing of two-rowed malt barley variety BH-885 was done on 28th November by pora method at 5-6 cm depth using different seed rate and row spacing as per treatments. Recommended dose of P (30 kg ha^{-1}) and K (15 kg ha^{-1}) and half dose of N as per treatments were applied at the time of sowing and remaining half dose of nitrogen as per treatments was top dressed at 1st irrigation at 45days after sowing. The crop was raised as per recommended package of practices, CCS HAU, Hisar (Anonymous 2014) [2].

The dry matter accumulation recorded at maturity by cutting plants in 0.25 metre row length from the second row on either side in each plot, representing the whole plot. At the time of selection, it was taken care that area of 0.50 metre near the bunds is excluded for sampling. These samples were first sun dried and then oven dried at 65±2 ^{0}C till a constant weight was obtained at each stage. After drying, the samples were weighted for recording dry weight in grams, and then dry matter per square metre was computed. NPK content in grain and straw at harvest was determined. For analysis of NPK oven dried plant material (grain and straw at harvest) from each plot was grinded separately with grinder. Nitrogen (Nessler's reagent method, Lindner, 1944) [16], phosphorus (Vanadomolybdo-phosphoric acid yellow colour method, Jackson, 1973) and potassium (Flame photometer method, Richards, 1954) contents in samples were analyzed. The uptake of each nutrient was computed as:

$$\text{Nutrient uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in grain (\%) x grain yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in straw (\%)} \times \text{straw yield (kg ha}^{-1}\text{)}}{100}$$

The nitrogen efficiency ratio (NER), physiological efficiency index of absorbed nitrogen (PEIN), nitrogen harvest index (NHI) and per cent soil N utilization (PSNU) was calculated using the following formulas:

$$\text{Nutrient efficiency ratio (NER)} = \frac{\text{Dry matter yield at harvest (kg ha}^{-1}\text{)}}{\text{N accumulation in crop at harvest (kg ha}^{-1}\text{)}}$$

$$\text{Physiological efficiency index of absorbed N (PEIN)} = \frac{\text{Grain yield produced (kg ha}^{-1}\text{)}}{\text{N absorbed in above dry matter at harvest (kg ha}^{-1}\text{)}}$$

$$\text{Nutrient harvest index (NHI)} = \frac{\text{Nitrogen uptake by the grain (kg ha}^{-1}\text{)}}{\text{Nitrogen uptake by the whole plant (kg ha}^{-1}\text{)}}$$

$$\text{Per cent soil N utilization (PSNU)} = \frac{\text{Ut}}{\text{Na} + \text{Np}} \times 100$$

Where

Ut = Uptake by the treatment

Na = Nutrient applied to the treatment

Np = Available soil nutrient in kg ha^{-1}

Results and Discussion

Dry matter accumulation and yield

Dry matter accumulation was significantly higher with the application of100 kg ha^{-1} seed rate as compared to 87.5 kg ha^{-1} (Fig.1). These results are in agreement with the findings of Sharifi and Raei (2011) [29] and Wiersma (2002) [36]. The higher dry matter accumulation with 100 kg ha^{-1} seed rate also led to higher grain yield in comparison to seed rate of 87.5 kg ha^{-1}.

The higher dry matter production was with row spacing of 18 cm and it decreased significantly with increasing row spacing from 18 cm to 20 and 22 cm. The increase in dry matter accumulation with 18 cm row spacing ranged from 4.6 to 4.8% over 20 cm and 7.4 to 7.6% over 22 cm row spacing at various growth stages. These results were supported by the fact that narrow row spacing caused higher leaf photosynthesis and suppressed weeds growth as compared to wider row spacing, as observed by Dwyer *et al*. (1991) [5]. These results are in line with the findings of Tollenaar and Auguilera (1992) [34] and Egly and Guffy (1997) [6]. The higher dry matter accumulation in narrow row spacing of 18 cm consequently led to higher grain yield (Fig. 1). Similar results were reported by Papworth (2010) [24].

The dry matter yield increased significantly with increase in nitrogen level only up to 90 kg N ha^{-1}, but further increase in nitrogen level to 105 kg N ha^{-1} could not produce significant improvement in dry matter yield. The increase in dry matter was 8.3, 11.9 and 13.9% with 75, 90 and 105 kg N ha^{-1} compared to 60 kg N ha^{-1}, respectively. Similar observations were also reported by Alam *et al*. (2005) [1], Natr (1997) [20], Sonmez (2000) [32] and Sandhu (2006) [28]. The grain yield followed the dry matter accumulation pattern with increasing levels of nitrogen.

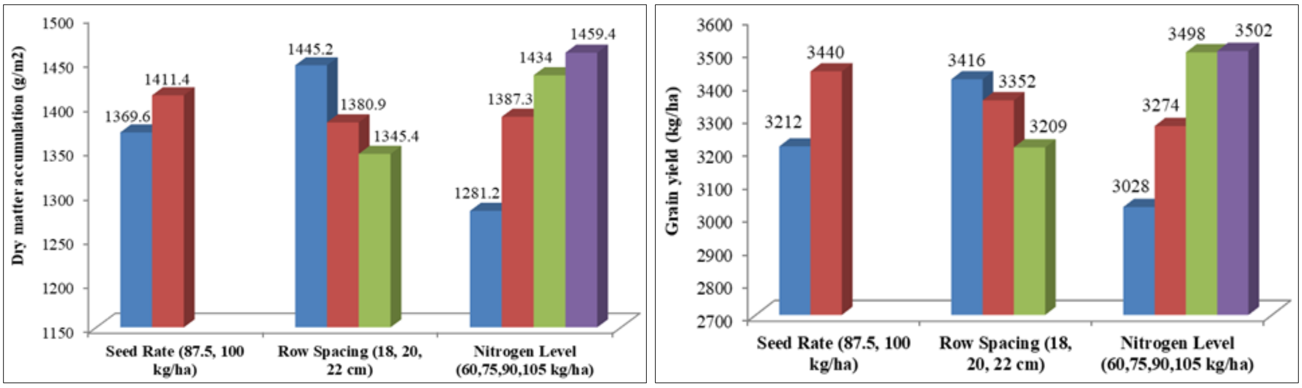

Fig 1: Effect of seed rate, row spacing and nitrogen levels on dry matter accumulation and grain yield

Nutrient content and uptake

The N, P and K content of grains and straw were not significantly affected by the different treatments of seed rate and row spacing. The P and K content of grain and K content of straw were also not significantly influenced by different levels of nitrogen (Table 1). However, the highest N content of grains and N and P content of straw was recorded at 105 kg N ha^{-1} which were at par with 90 kg N ha^{-1} but significantly higher than 75 and 60 kg N ha^{-1}. Taalab *et al*. (2015**)** [33] reported that nitrogen content and uptake by grain and straw increased with increasing nitrogen from 70 to 100 kg N ha^{-1}.

Table 1: Effect of seed rate, row spacing and nitrogen levels on nutrient content and uptake of malt barley

Treatments	Nutrient content in grain (%)			Nutrient content in straw (%)			Nutrient uptake by grain (kg ha^{-1})			Nutrient uptake by straw (kg ha^{-1})			Total nutrient uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Seed rate (kg ha^{-1})															
87.5	1.71	0.40	0.49	0.31	0.22	1.58	55.11	12.88	15.89	23.28	15.94	117.03	78.40	28.82	132.94
100.0	1.69	0.41	0.49	0.31	0.22	1.57	58.13	14.06	17.04	23.87	16.32	119.52	82.01	30.38	136.57
S.Em±	0.02	0.01	0.01	0.003	0.001	0.01	0.80	0.24	0.26	0.30	0.14	1.24	0.79	0.27	1.24
CD at 5%	NS	NS	NS	NS	NS	NS	2.52	0.77	0.82	NS	NS	NS	2.50	0.85	NS
Row spacing (cm)															
18.0	1.72	0.40	0.49	0.31	0.22	1.56	58.75	13.77	16.84	24.00	16.66	120.36	82.75	30.43	137.21
20.0	1.67	0.41	0.49	0.32	0.22	1.58	56.13	13.88	16.31	23.75	16.24	119.73	79.89	30.13	136.05
22.0	1.71	0.39	0.51	0.32	0.21	1.57	54.99	12.76	16.27	22.98	15.48	114.73	77.97	28.45	131.01
S.Em±	0.02	0.01	0.01	0.003	0.002	0.02	0.98	0.30	0.32	0.37	0.17	1.52	0.97	0.33	1.52
CD at 5%	NS	NS	NS	NS	NS	NS	NS	0.95	NS	NS	0.55	4.79	3.06	1.05	4.79
Nitrogen Levels (kg ha^{-1})															
60	1.62	0.39	0.49	0.30	0.21	1.55	48.86	11.96	14.73	20.73	14.11	106.33	69.60	26.07	121.06
75	1.69	0.41	0.50	0.31	0.21	1.56	55.23	13.51	16.26	23.06	15.93	116.67	78.29	29.46	132.93
90	1.73	0.41	0.50	0.32	0.22	1.59	60.57	14.39	17.46	24.79	16.96	122.72	85.36	31.36	140.19
105	1.76	0.40	0.50	0.32	0.22	1.59	61.83	14.01	17.44	25.73	17.51	127.39	87.57	31.53	144.84
S.Em±	0.02	0.01	0.01	0.001	0.003	0.02	0.89	0.41	0.31	0.27	0.31	1.56	0.94	0.47	1.45
CD at 5%	0.06	NS	NS	0.004	0.01	NS	2.56	1.16	0.88	0.76	0.88	4.48	2.69	1.34	4.17

The data presented in table 1 indicated that N, P and K uptake of grain and total N and P uptake was significantly higher in treatment having seed rate of 100 kg ha^{-1} than 87.5 kg ha^{-1} seed rate. However, the N, P and K uptake of straw as well as total K uptake were not significantly affected by seed rate as the content was not influenced by seed rate. The higher uptake by grain was mainly due to higher grain yield. However, non-significant difference in straw uptake was due to the fact that nutrients from straw translocated towards the grains.

Different row spacing did not significantly influence the N and K uptake of grain and N uptake of straw (Table 1). However, total N uptake with 18 cm row spacing was significantly higher than 22 cm row spacing. However, the maximum P uptake of grain was recorded at 20 cm row spacing which was at par with 18 cm row spacing but significantly higher than 22 cm row spacing. The maximum P and K uptake of straw and total P and K uptake were recorded at 18 cm row spacing which was at par with 20 cm row spacing but significantly higher than 22 cm row spacing. Similarly, Bhullar and Walia (2003) [4] reported that wheat crop raised with closer row spacing (15 cm) recorded significantly higher uptake of NPK as compared to crop raised with wider row spacing (22 cm). However, Kumar (2001) [15] reported that in barley the NPK content in grain and straw and their uptake, total uptake and protein content did not differ significantly due to different row spacing (18, 20.5 and 23 cm).

The highest N uptake of grain and N, P and K uptake of straw as well as total uptake was recorded with 105 kg N ha^{-1} which was statistically at par with 90 kg N ha^{-1} except total K uptake but significantly higher than 75 and 60 kg N ha^{-1}. However, P and K uptake of grain was maximum at 90 kg N ha^{-1} but it was at par with 105 kg N ha^{-1} and significantly higher than 75 and 60 kg N ha^{-1}. This was mainly due to the fact that nutrient uptake followed the yield pattern which increased with increasing level of nitrogen. Fageria and Baligar (2001) [7] reported that N uptake in grain has positive significant associations with grain yield. Woldeyesus *et al*. (2004) [37] and Muurinen (2007) [19] reported significant increase in straw nitrogen uptake with increased N rates.

Correlation of dry matter yield with nutrient uptake and quality parameters

The correlation between total N, P and K uptake and dry matter accumulation was worked out, which was very strong and positive with determination factor of 0.982, 0.989 and 0.989 for total N, P and K uptake, respectively (Fig 2).

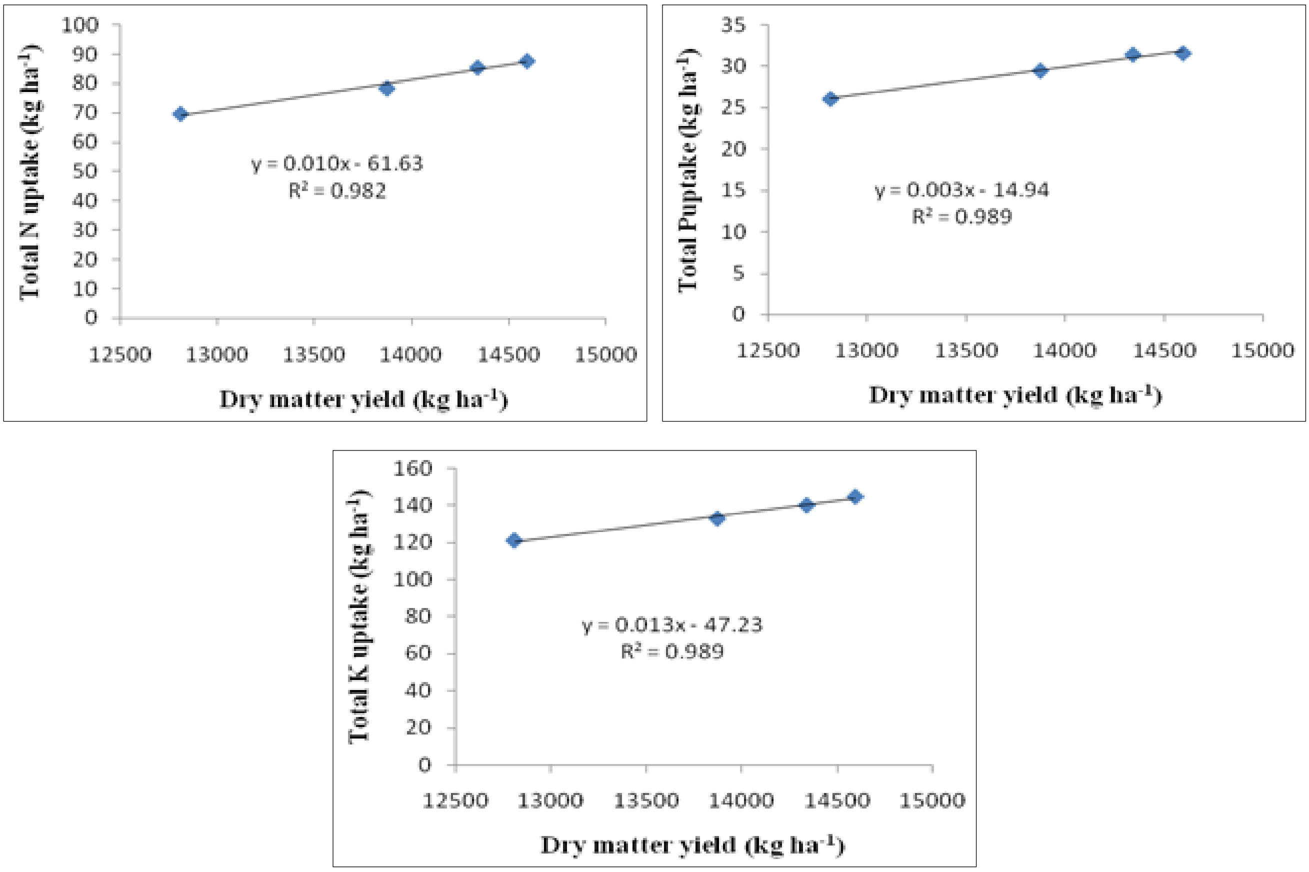

Fig 2: Relationship of total N, P and K uptake and dry matter yield

The mathematical relationship between the quality parameters and dry matter accumulation (Fig 3) revealed that grain husk and protein contents were strongly and positively correlated having determination factor of 0.973 and 0.980, respectively, whereas, grain starch and malt contents were negatively correlated with dry matter yield and having determination factor of 0.897 and 0.964, respectively.

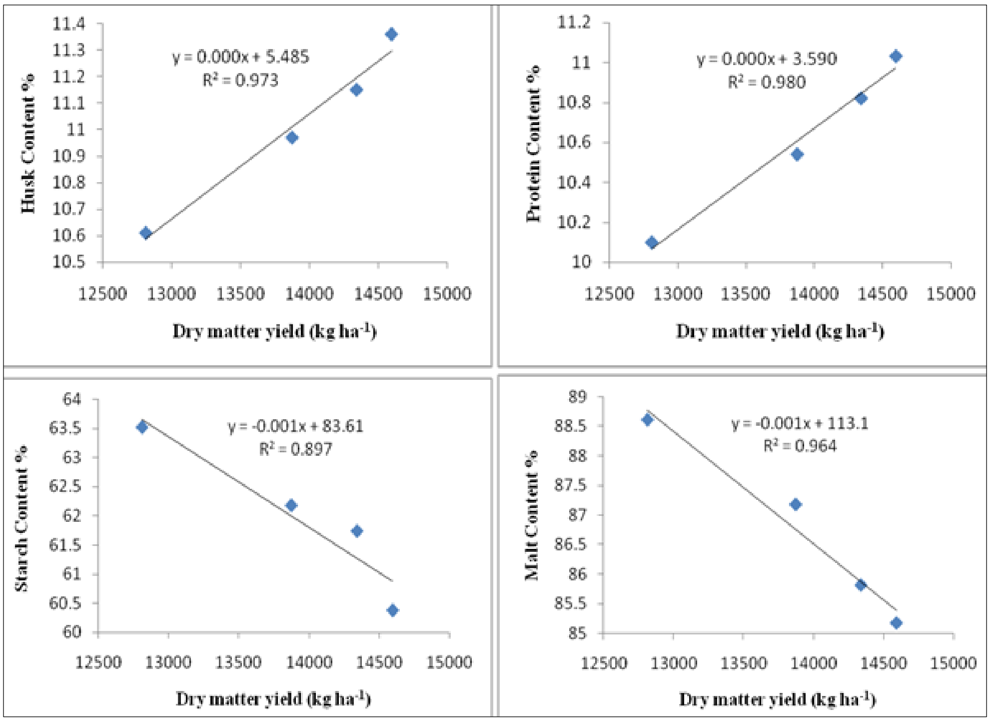

Fig 3: Relationship of quality parameters and dry matter yield

Correlation of nitrogen levels with NER, PEIN, NHI and PSNU

The increasing dose of nitrogen from 60 to 105 kg ha^{-1} remarkably decreased nitrogen efficiency ratio (NER) and physiological efficiency index of absorbed nitrogen (PEIN) with value of determination factor of 0.903 and 0.972, respectively (Fig 4). This could be explained due to the fact as the nitrogen application increased the grain yield, which had strong negative relationship with both NER and PEIN with R^2 values of 0.998 and 0.925, respectively (Fig 5). The nitrogen harvest index increased with increasing nitrogen dose upto 90 kg ha^{-1} but these were poorly correlated (R^2 = 0.512 (Fig 4). However, NER was also positively correlated with grain yield (R^2 = 0.813) and it increased as the grain yield increased with increasing nitrogen application (Fig 5). The per cent soil N utilization was very poorly correlated with nitrogen levels with determination factor of just 0.163 (Fig 4). It was mainly due to poor correlation of PSNU with grain yield with R^2 value of 0.459 (Fig 5).

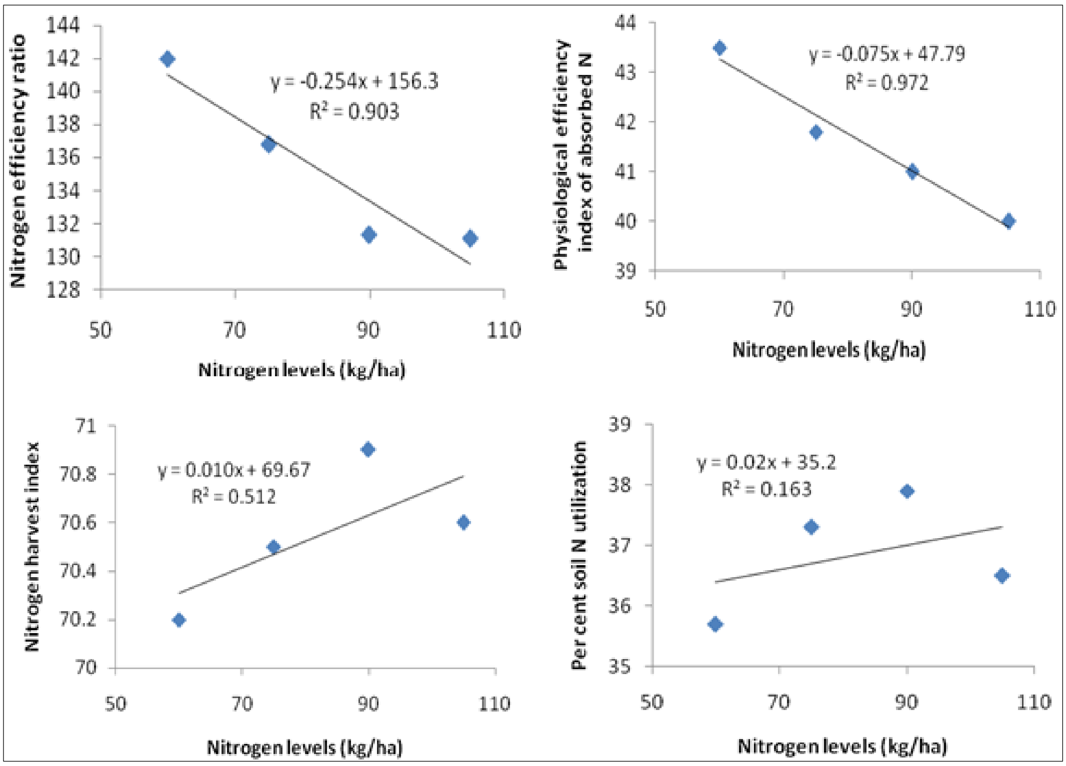

Fig 4: Relationship of NER, PEIN, NHI and PSNU with nitrogen levels

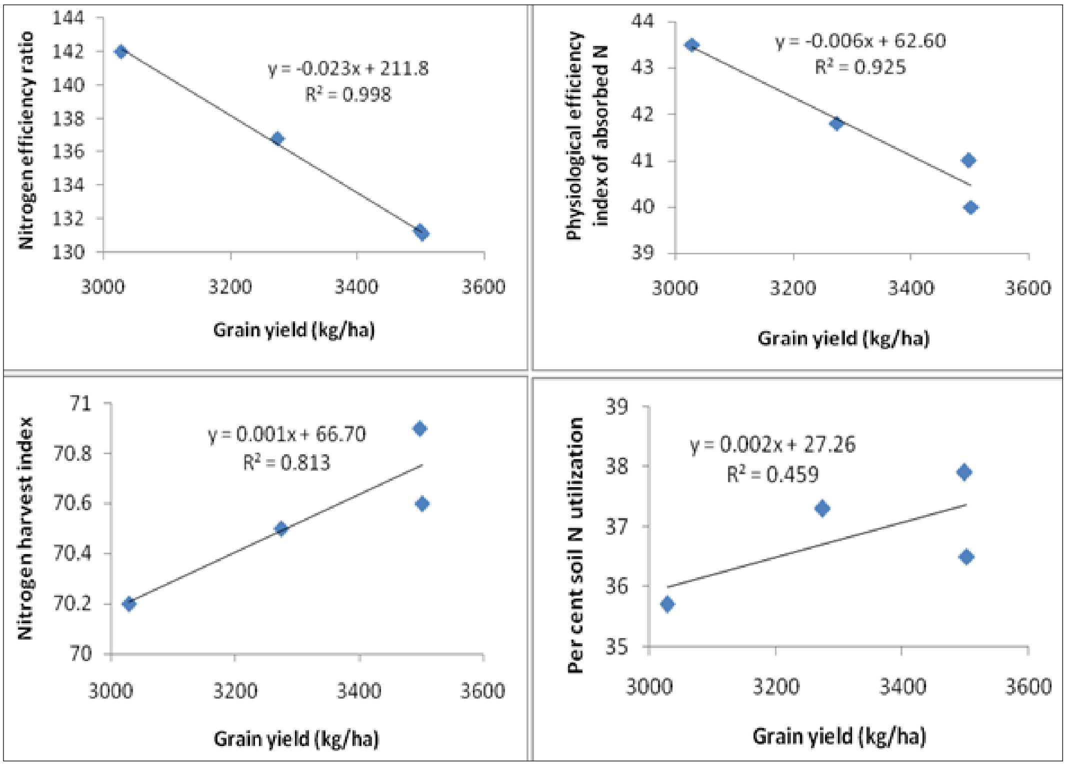

Fig 5: Relationship of NER, PEIN, NHI and PSNU with grain yield

Conclusion

It can be concluded that application of 100 kg seed rate for two-rowed barley was found optimum in terms of dry matter accumulation and nutrient uptake. Among row spacing, 18 cm and 20 cm were at par and were significantly better as compared to 22 cm in terms of dry matter accumulation and nutrient uptake by grain and straw. Application of 90 kg N ha^{-1} was found optimum in respect of dry matter yield and total nutrient uptake for two rowed barley variety BH 885. The total NPK uptake, grain husk and protein contents were highly and positively correlated with dry matter accumulation. The nitrogen efficiency ratio (NER) and physiological efficiency index of absorbed nitrogen (PEIN) decreased with increasing dose of nitrogen from 60 to 105 kg ha^{-1}. However, nitrogen harvest index increased with increasing nitrogen dose upto 90 kg ha^{-1}.

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