The Pharma Innovation Journal 2022; SP-11(4): 122-129

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(4): 122-129

www.thepharmajournal.com
Received: 28-02-2022
Accepted: 30-03-2022

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# Effect of seed rate, row spacing and nitrogen levels on thermal utilization, growth and yields of two rowed malt Barley

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**Abstract**
A field investigation was undertaken at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar. The aim of the experiment was to study the effect of different agronomic practices on heat unit requirement and also to quantify their relationship with growth parameters, malt and protein yields of two-rowed malt barley. The study comprised of two levels of seed rate (87.5 and 100 kg ha$^{-1}$) and three spacings (18, 20 and 22 cm) in main plots and four levels of nitrogen (60, 75, 90 and 105 kg/ha) in sub plots. The treatments were laid out in split plot design with three replications. The dry matter accumulation, LAI and number of tillers at all stages as well as grain, malt and protein yield improved significantly with the use of 100 kg seed rate, 18 and 20 cm row spacing and 90 kg N/ha. However, GDD, PTU and HTU were significantly higher with the application of 105 kg N/ha as compared to lower levels of nitrogen. Dry matter accumulation, LAI, number of tillers, grain, malt and protein yield had positive and strong correlation with agro-meteorological indices.

**Keywords:** GDD, PTU, HTU, LAI, Dry matter accumulation, malt and protein yield, seed rate, row spacing, nitrogen level, correlation

## Introduction

Barley is a multipurpose cereal crop which is grown for feed, fodder and malt. This crop has wide adaptability under different environmental conditions and agro-ecological situation from the desert of the Middle East to the high elevation of Himalayas (Hingonia *et al*., 2016) [7]. It has the place of pride in cereal based cropping systems and ranks fourth in the world after wheat, rice and maize (Pal *et al*., 2012) [13]. This crop tolerates adverse and stressful conditions better than any other cereal and has the productivity edge in such situations. The area, production and productivity of this crop in India is 5.90 lakhs ha area, 17.20 lakhs tons and 2.9 metric tons ha$^{-1}$, respectively (Anonymous 2020-21) [2]. The potential productivity realization requires the best suited and location specific production package but seed rate and row spacing proves critical for better growth, dry matter production and yield (O'Donovan *et al*., 2011) [12, ] of malt barley. In order to fulfill the increasing demand of malt barley in India, breeding of varieties with higher yield coupled with malt content and thus with higher malt yield has been the thrust area for last many years. The agronomic practices for malt barley may vary from those recommended for its feed crop. The majority of the soils in the world are deficient in nitrogen and it has to be supplemented through organic sources or chemical fertilizers. Thus, proper nitrogen management within the ambit of balanced crop nutrition is of high importance for increasing grain and malt yield and economic returns of the farmers; also to improve the quality in terms of amino acid constitution and protein content. The increased application of nitrogen was found to have positive impact on dry matter accumulation (Singh *et al*., 2013) [16], yield (Kakraliya *et al*., 2017) [10] and quality (O'Donovan *et al*., 2011 and Singh *et al*., 2013) [12, 16] in barley crop.

The crop adaptation through agro-meteorological interventions is equally important to address the inherent environmental risks and to mitigate the impact of climate change (Bemal *et al*., 2013 and Kumar *et al*., 2013) [3, 11]. Nitrogen management has direct impact on vegetative growth of barley and thereby decides the amount of light interception by the plant and the crop canopy temperature. Temperature, bright sunshine hours and day length decides the crop phenological behavior, growth, development and yield. Temperature effects the growth and development of barley crop by regulating its growth and also by regulating the transitional time period intervening different developmental stages in plant ontogeny.

The temperature based indices, GDD or heat unit requirement has been used for mapping the thermal response in crop plant. The grain yield and physiological maturity of various crops can be predicted by correlating the heat units or GDD concept to phenological development (Haider *et al*., 2003) [6]. The agronomic and physiological aspects of crop growth in barley have been widely studied but not much work has been done in two rowed malt barley as to define the relationship of growth and yield with heat units and variations therein under variable seed rate, row spacing and nitrogen levels. In the backdrop of all these factors, the performance of two-rowed malt barley cultivar BH 885 was evaluated to study the effect of different agronomic practices like seed rate, row spacing and nitrogen levels on heat unit requirement; and also to quantify their relationship with growth parameters, malt and protein yield as to define a best suited agronomic practices for northern Indo Gangetic Plains of India.

## Materials and Methods

The field study was undertaken during *rabi* 2014-15 at Research Farm, Department of Agronomy, CCSHAU, Hisar, Haryana (India). The farm is located at 29°10' N latitude and 75° 46' E longitude at an elevation of 215.2 m above msl. The soil was sandy loam in texture with slightly alkaline in reaction (pH 8.3), low in organic carbon (0.32%) and available nitrogen (135 kg N/ha), medium in available phosphorus (17 kg P/ha) and high in available potassium (334 kg K/ha). The experiment was conducted in split plot design with three replications; six main plots had combination of two seed rates (87.5 and 100 kg/ha) and three spacings (18, 20 and 22 cm) and four nitrogen levels (60, 75, 90 and 105 kg N/ha) in sub plots. The variety BH-885 of two-rowed malt barley was used in the study and sowing was on 28th November by pora method at 5-6 cm depth while varying the seed rate and row spacing as per treatments. Recommended dose of P (30 kg/ha)and K (15 kg/ha)and half dose of N as per treatments were applied at the time of sowing and remaining half dose of N as per treatments was top dressed at 1st irrigation at 45 days after sowing. The recommended package of practices, CCS HAU, Hisar was followed to raise the crop (Anonymous 2014) [1].

The dry matter accumulation was recorded at 30, 60, 90, 120 DAS and at maturity. The tillers were recorded at 45, 90, 120 DAS and at maturity. The area of green leaves (photo synthetically active) was recorded at 30, 60, 90 and 120 DAS and LAI was worked out using standard method. The tillers were counted at 45, 90, 120 DAS and at maturity. During crop season the meteorological data, *viz*., rainfall, relative humidity, maximum and minimum temperature, bright sunshine hours and pan evaporation *etc*. were recorded from Agro-meteorological observatory, Chaudhary Charan Singh Haryana Agricultural University; Hisar has given in (Fig. 1). The statistical analysis was done using OPSTAT programme available online on CCS HAU, Hisar web site. The temperature based meteorological indices were calculated using the standard formulae (Gill *et al*., 2014) [5].

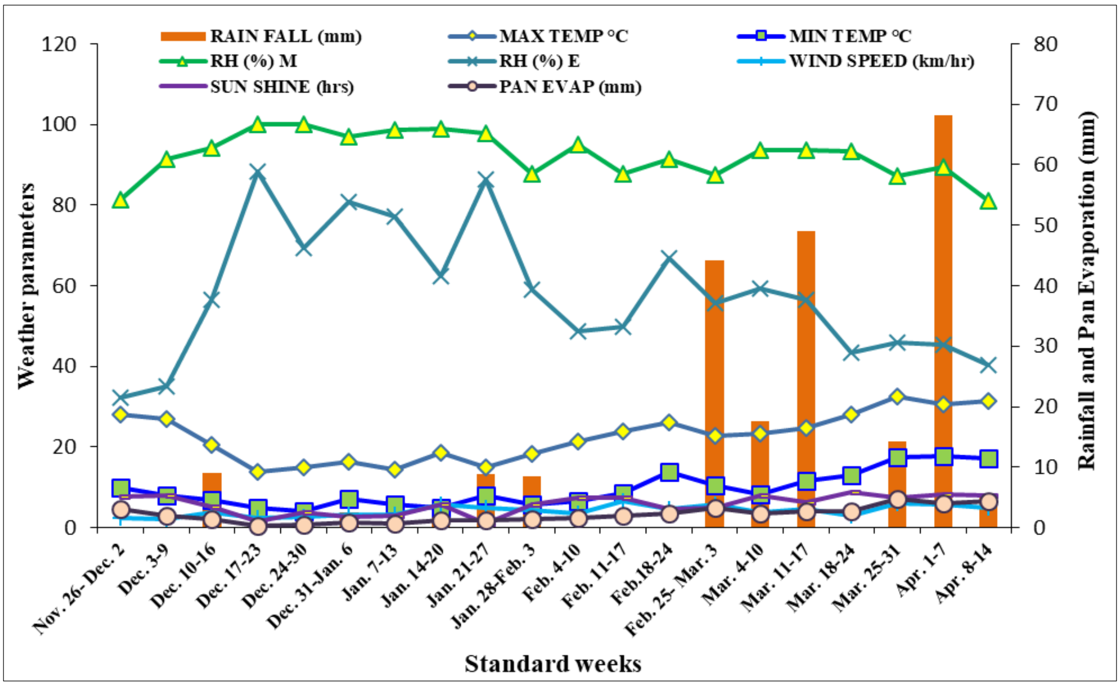


**Fig 1:** Mean weekly weather data of Agrimet Observatory, CCS HAU, Hisar *rabi* (2014-2015)

## Results and Discussion

### Growing Degree Days/Heat units

Increasing trend was observed in case of GDD or heat unit requirement, PTU and HTU with the advancement of crop growth. The rate of progressive increase was comparatively slow during the initial period of growth *i.e.* tillering to jointing, then increased from jointing to anthesis and thereafter again decreased during anthesis to dough stages (Fig. 2).

The agro-meteorological indices *viz.* GDD, PTU and HTU under both the seed rates (85 and 100 kg/ha) were statistically at par (Fig. 2). Though their higher value were recorded at the inter row spacing of 18 cm than the spacing of 22 cm but the difference was not statistically significant. As there were no major environmental differences due to row spacing which could have influenced the phenophases of the crop under different row spacings. The data presented in Fig. 2 further indicated that application of 105 kg N/ha significantly enhanced the agro-meteorological indices at all the stages of crop growth than the lower levels of nitrogen except at jointing stage where both 90 kg and 105 kg N/ha were statistically similar.

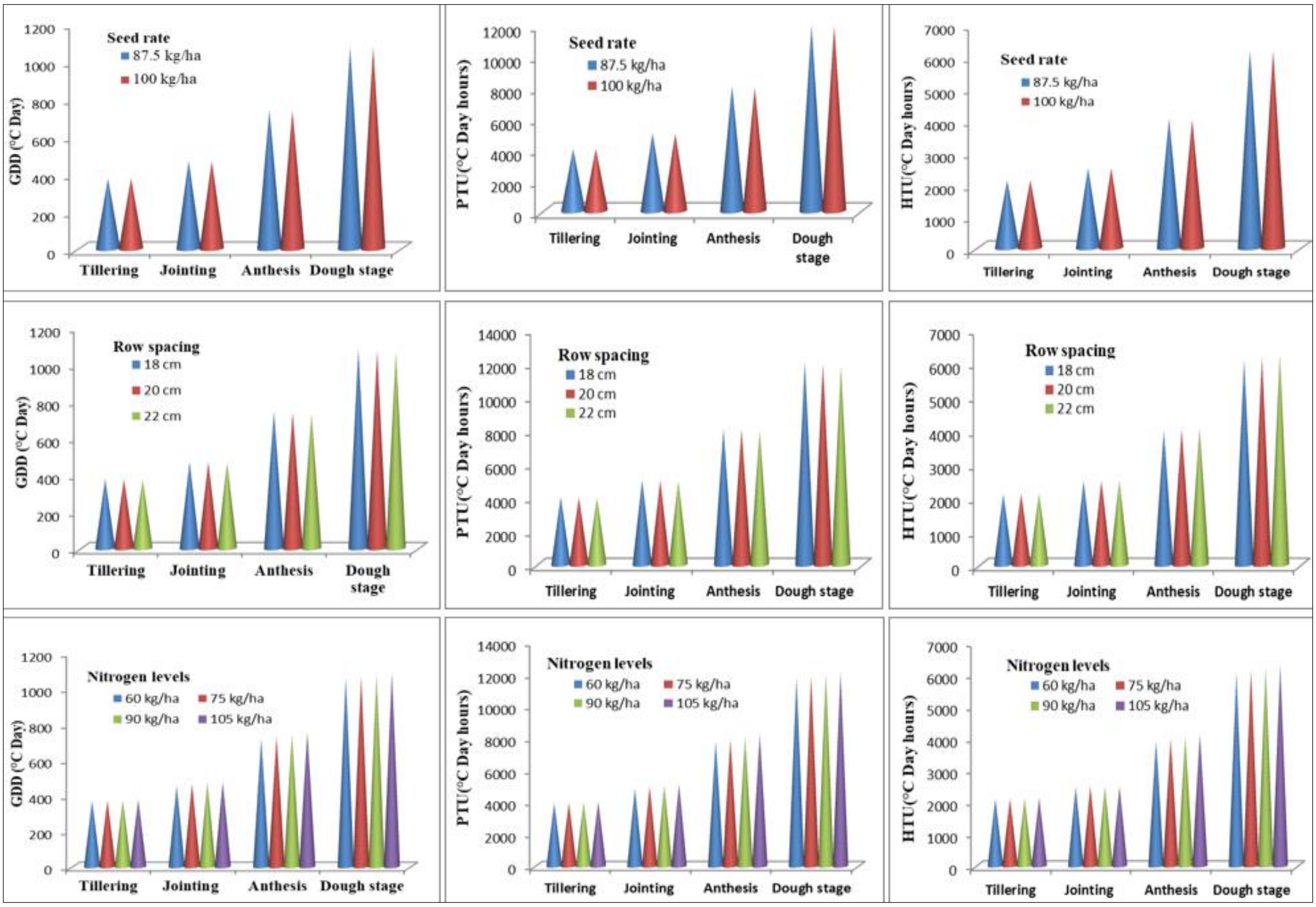


**Fig 2:** Effect of seed rate, row spacing and nitrogen levels on GDD, PTU and HTU

## Leaf area index and Tillers

Leaf area index increased with the advancement of crop age upto 90 DAS and it decreased thereafter at 120 DAS due to leaf senescence and tiller mortality at later growth stages (Table 1). The LAI was significantly higher with seed rate of 100 kg/ha at 30, 60 and 90 DAS as compared to seed rate of 87.5 kg/ha. However, at 120 DAS both seed rates did not differ significantly in respect of LAI.

**Table 1:** Effect of seed rate, row spacing and nitrogen levels on leaf area index and tillers

| Treatments | Leaf area index (LAI) | | | | Tillers (Number/m$^2$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 45 DAS | 90 DAS | 120 DAS | At Maturity |
| **Seed rate (kg/ha)** | | | | | | | | |
| 87.5 | 1.49 | 2.31 | 3.13 | 0.114 | 724 | 756 | 744 | 706 |
| 100.0 | 1.55 | 2.49 | 3.30 | 0.116 | 740 | 775 | 763 | 723 |
| S.Em± | 0.01 | 0.02 | 0.02 | 0.001 | 3.48 | 4.0 | 4.4 | 4.0 |
| CD at 5% | 0.02 | 0.07 | 0.07 | NS | 10.9 | 12.7 | 13.9 | 12.7 |
| **Row spacing (cm)** | | | | | | | | |
| 18.0 | 1.55 | 2.48 | 3.32 | 0.117 | 796 | 831 | 818 | 776 |
| 20.0 | 1.52 | 2.41 | 3.23 | 0116 | 728 | 763 | 751 | 712 |
| 22.0 | 1.47 | 2.30 | 3.14 | 0.112 | 673 | 702 | 691 | 655 |
| S.Em± | 0.01 | 0.03 | 0.03 | 0.002 | 4.3 | 4.9 | 5.4 | 4.9 |
| CD at 5% | 0.02 | 0.08 | 0.09 | NS | 13.4 | 15.6 | 17.0 | 15.6 |
| **Nitrogen level (kg/ha)** | | | | | | | | |
| 60 | 1.38 | 2.23 | 2.78 | 0.106 | 695 | 730 | 717 | 681 |
| 75 | 1.49 | 2.36 | 3.14 | 0.114 | 727 | 759 | 747 | 708 |
| 90 | 1.59 | 2.50 | 3.45 | 0.119 | 750 | 783 | 771 | 730 |
| 105 | 1.60 | 2.51 | 3.53 | 0.123 | 756 | 790 | 779 | 738 |
| S.Em± | 0.02 | 0.03 | 0.03 | 0.002 | 3.1 | 4.0 | 4.3 | 4.2 |
| CD at 5% | 0.04 | 0.09 | 0.09 | 0.007 | 8.8 | 11.6 | 12.3 | 12.1 |

Also the row spacing had significant effect on LAI at 30, 60 and 90 DAS and it increased with the decrease in row spacing. The maximum LAI was recorded with row spacing of 18 cm followed by 20 cm and minimum with 22 cm row spacing. As in narrow row spacing higher leaf photosynthesis and more suppression of weed growth occurs in comparison to wider row spacing. However, at 120 DAS, LAI was not influenced significantly by row spacing. The results of present investigation are in line with the findings of Iqbal *et al.* (2012) [9].

The LAI improved significantly with the increase in nitrogen levels upto 90 kg N/ha at all the crop growth stages. The maximum LAI was recorded with 105 kg N/ha which was statistically at par with 90 kg N/ha and both these treatments have significantly higher LAI than 75 and 60 kg N/ha at all the crop growth stages but at 120 DAS 75 and 90 kg N/ha levels were statistically at par in respect of LAI. The improvement in LAI with increased nitrogen application may be due to the fact that nitrogen plays an important role in the cell division and cell elongation process which contributed to enhancement in the number of lateral (side) tillers which consequently resulted in higher leaf area index. The results of present study are in conformation with the findings of Singh *et al.* (2013) [16].

The number of tillers increased slightly upto 90 DAS and thereafter marginally decreased at 120 DAS and maturity because of tiller mortality at later growth stages. The seed rate of 100 kg/ha resulted into significantly higher number of tillers over the seed rate of 87.5 kg/ha at 45, 90, 120 DAS and at maturity. This was mainly due to fact that as the seed rate increased more number of plants per unit area will also increase which ultimately resulted into higher number of tillers under higher seed rate treatment. These results are in agreement with the findings of Ijaz *et al.* (2002) [8].

Among different row spacing treatments, significantly higher number of tillers/m$^2$ were recorded with row spacing of 18 cm as compared to 20 and 22 cm row spacing. The later two row spacings were also differed significant with respect to number of tillers/m$^2$. Increase in number of tillers/m$^2$ with decreasing row spacing was also reported by Shah (2000) [15].

The maximum number of tillers/m$^2$ was recorded with 105 kg N/ha which was statistically at par with 90 kg N/ha but both were significantly higher than 75 and 60 kg N/ha at 45, 90, 120 DAS and at maturity. The improvement in number of tillers/m$^2$ with increased nitrogen application may be due to the fact that nitrogen plays an important role in the cell division and cell elongation process which contributed to enhancement in the number of lateral (side) tillers. The results of present investigation are in agreement with the findings of Singh *et al.* (2013) [16].

**Dry matter accumulation and yields**

Dry matter accumulation at various growth stages increased progressively from vegetative to harvest phase. Its rate of accumulation was slow up to initial 30 days and highest between 30 to 60 DAS and thereafter the increase was at a decreasing rate up to maturity (Table 2). It was significantly higher with 100 kg/ha seed rate in comparison to 87.5 kg/ha at all crop growth stages. Since with increase in seed rate more number of plants per unit area will increase leading to enhance the leaf area index, which is one of the ways of increasing the capture of solar radiation within the canopy and accumulation of more photosynthates. Similar results were also reported by Ijaz *et al*. (2002) [8]. The higher dry matter production with 100 kg/ha seed rate consequently resulted into higher grain yield as compared to 87.5 kg seed/ha. The same trend was observed with respect to malt and protein yields as that of grain yield with increasing seed rate.

**Table 2:** Effect of seed rate, row spacing and nitrogen levels on dry matter accumulation and yields

| Treatments | Dry matter accumulation (g/m$^2$) | | | | | Yields (q/ha) | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | At Maturity | Grain | Protein | Malt |
| **Seed rate (kg/ha)** | | | | | | | | |
| 87.5 | 46 | 221 | 936 | 1256 | 1370 | 32.12 | 3.44 | 27.69 |
| 100.0 | 47 | 228 | 965 | 1295 | 1411 | 34.40 | 3.64 | 29.94 |
| S.Em± | 0.3 | 1.8 | 5.3 | 6.9 | 7.6 | 0.23 | 0.05 | 0.22 |
| CD (P=0.05) | 0.8 | 5.6 | 16.8 | 21.9 | 24.1 | 0.72 | 0.15 | 0.70 |
| **Row spacing (cm)** | | | | | | | | |
| 18.0 | 48 | 233 | 988 | 1325 | 1445 | 34.16 | 3.67 | 29.66 |
| 20.0 | 46 | 223 | 944 | 1266 | 1381 | 33.52 | 3.51 | 29.17 |
| 22.0 | 45 | 217 | 919 | 1234 | 1345 | 32.09 | 3.44 | 27.61 |
| S.Em± | 0.3 | 2.2 | 6.5 | 8.5 | 9.3 | 0.28 | 0.06 | 0.27 |
| CD (P=0.05) | 1.0 | 6.8 | 20.5 | 26.8 | 29.3 | 0.89 | NS | 0.86 |
| **Nitrogen levels (kg/ha)** | | | | | | | | |
| 60 | 43 | 207 | 875 | 1175 | 1281 | 30.28 | 3.06 | 26.84 |
| 75 | 46 | 222 | 949 | 1273 | 1387 | 32.74 | 3.45 | 28.55 |
| 90 | 48 | 233 | 981 | 1314 | 1434 | 34.98 | 3.79 | 30.03 |
| 105 | 49 | 235 | 997 | 1339 | 1459 | 35.02 | 3.87 | 29.83 |
| S.Em± | 0.3 | 2.4 | 6.8 | 9.4 | 10.3 | 0.40 | 0.09 | 0.35 |
| CD (P=0.05) | 0.9 | 6.8 | 19.6 | 26.9 | 29.5 | 1.26 | 0.27 | 1.01 |

The dry matter accumulation was maximum with 18 cm row spacing and it decreased significantly with each increasing row spacing of 20 cm and 22 cm at all the growth stages. This was due to the fact that in narrow row spacing higher leaf photosynthesis and more suppression of weed growth occurs in comparison to wider row spacing, which resulted into more dry matter accumulation. The results of present study are in conformation with the findings of Iqbal *et al.* (2012) [9]. The higher dry matter production with narrow row spacing of 18 cm resulted into higher grain yield (Table 2) than the other two spacings. Similar observations were also reported by Paynter (2010). The malt and protein yields also followed the grain yield pattern with each level of decreasing the row spacing from 22 cm to 18 cm.

The dry matter accumulation increased significantly with increase in nitrogen dose up to 90 kg/ha at all the crop growth stages. However, further increase in N dose to 105 kg N/ha did not significantly improve it in comparison to 90 kg N/ha. These results were supported by the fact that increased N application enhanced the cell division and cell elongation process leading to increased leaf area and more tillers which resulted in higher dry matter production. The increase in dry matter with the increasing dose of N in barley has been also reported by Singh *et al.* (2013) [16]. The same trend was followed by the grain yield with increasing nitrogen levels as that of dry matter accumulation. Malt and protein yields are governed by malt and protein content and grain yield. As the grain yield increased with increasing nitrogen levels consequently the malt and protein yields were also increased.

**Relationship of growth parameters with GDD**

Dry matter accumulation, leaf area index (LAI) and number of tillers have positive and strong relationship with GDD or heat units at all the phenological stages (Fig. 3). The determination factor ($R^2$) for dry matter accumulation was 0.989, 0.860 and 0.903 and for LAI was 0.963, 0.905 and 0.969 at jointing, anthesis and dough stage, respectively. While for number of tillers the determination factor ($R^2$) was 0.846, 0.911 and 0.949 at tillering, anthesis and dough stage, respectively.

**Relationship of agro-meteorological indices with malt and protein yield**

Malt yield had positive and strong correlation with agro-meteorological indices *viz.* GDD, PTU and HTU at the reproductive stages *i.e* anthesis and dough stages (Fig. 4). Malt yield is the product of malt recovery % and grain yield but malt recovery % was negatively correlated with GDD while the grain yield had positive and strong correlation with GDD (Dahiya *et al*., 2019) [4]. Protein yield had positive and strong correlation with GDD, PTU and HTU at anthesis and dough stages (Fig. 5). Protein yield is the product of protein content and grain yield, however protein content also had positive and strong correlation with GDD with determination factor of 0.968 at dough stage (Dahiya *et al*., 2019) [4].

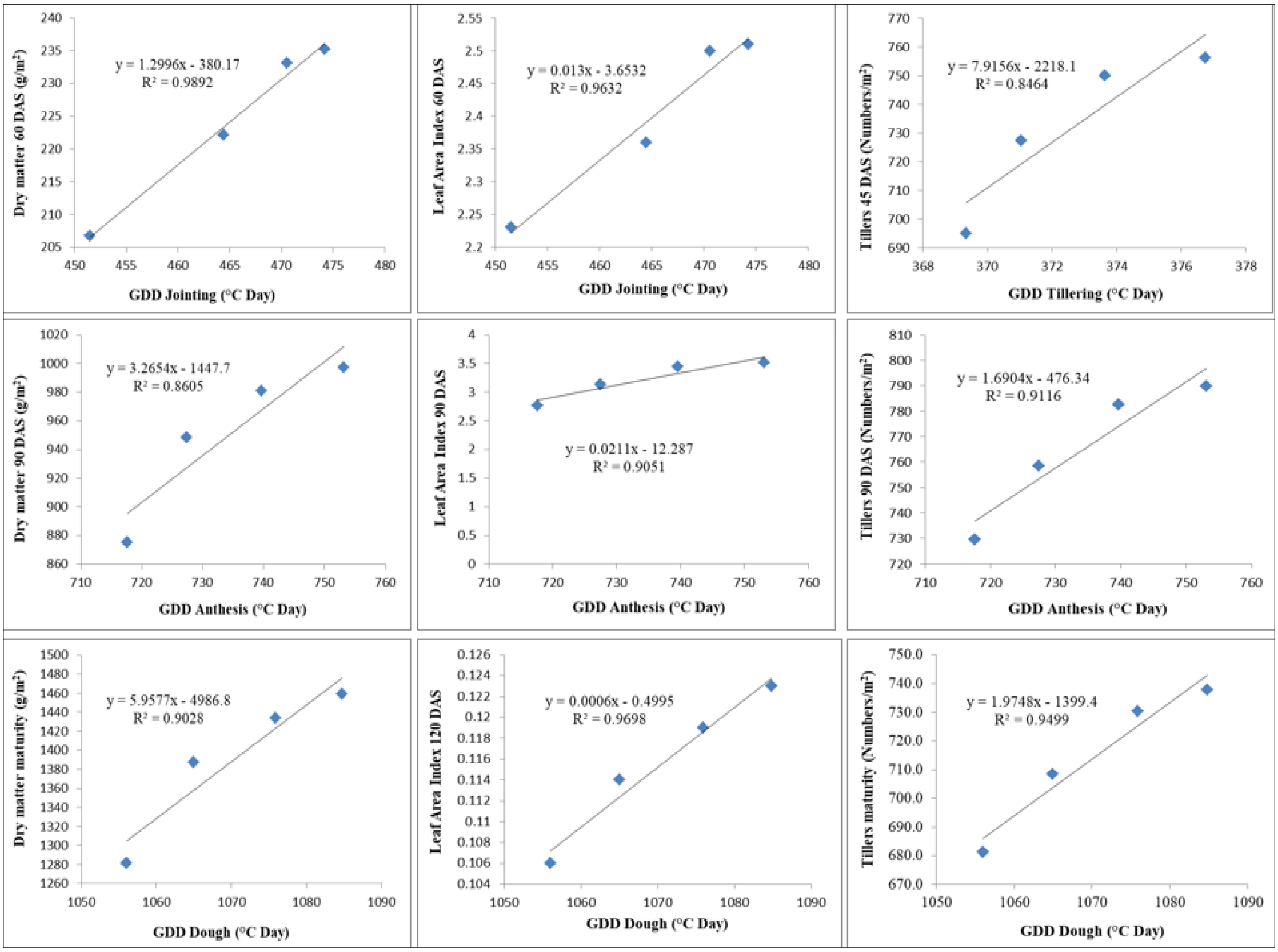


**Fig 3:** Relationship of growth parameters (dry matter accumulation, LAI, tillers) with growing degree days (GDD)

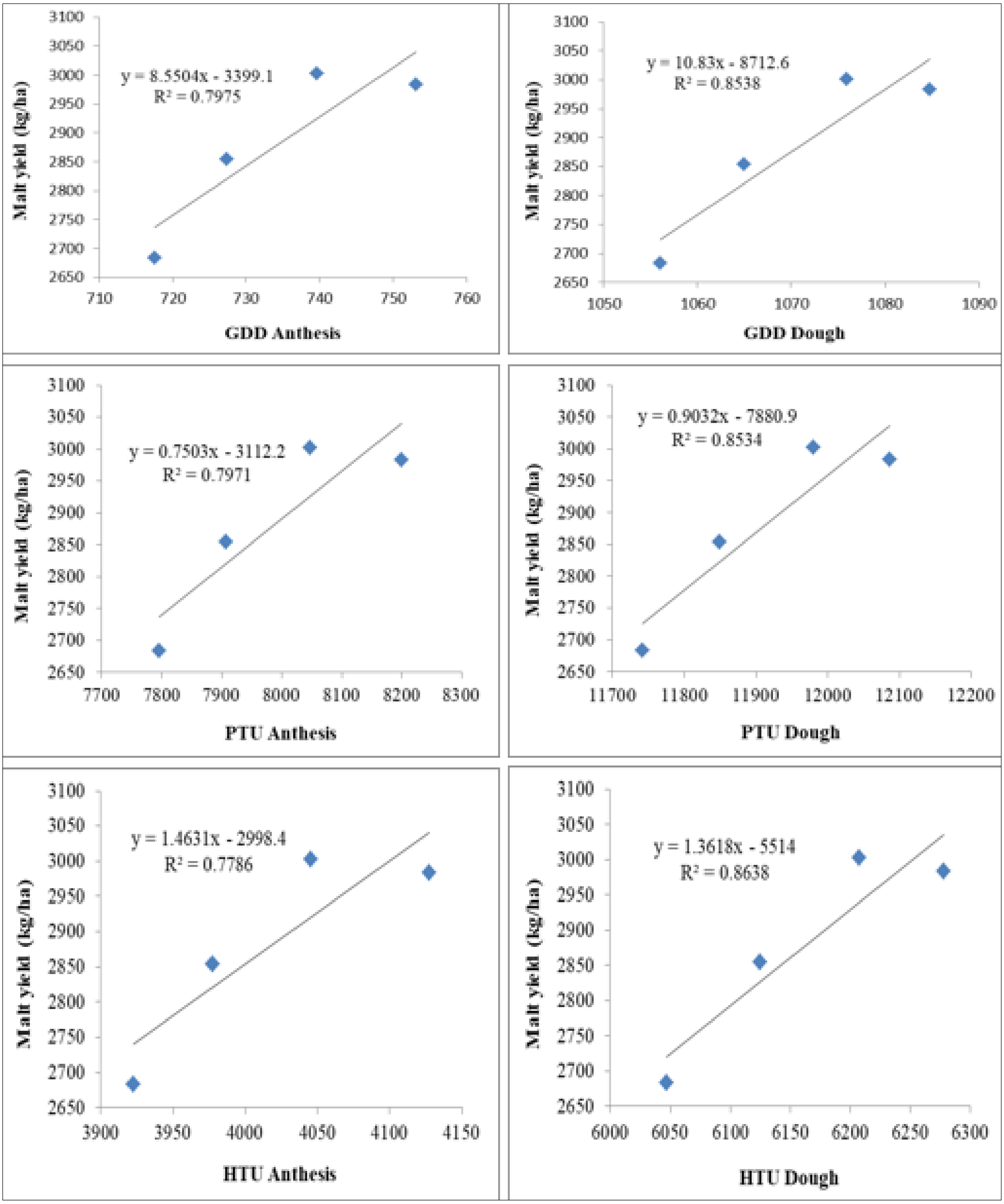


**Fig 4:** Relationship of malt yield with agro-meteorological indices

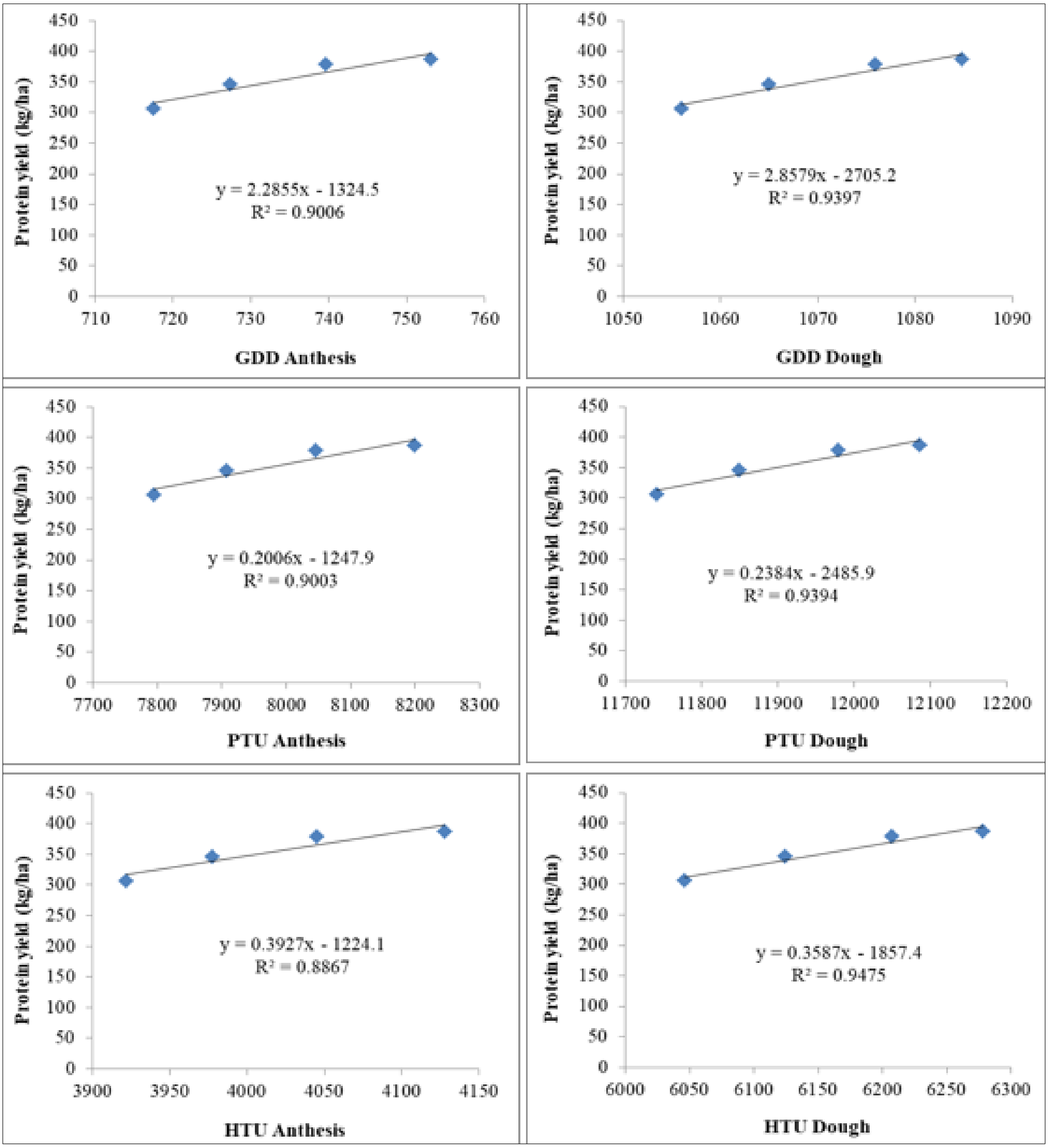


**Fig 5:** Relationship of protein yield with agro-meteorological indices

## Conclusion
It can be concluded that use of 100 kg seed rate, 18 and 20 cm row spacing and 90 kg N/ha were found best with respect to dry matter accumulation, LAI, number of tillers, grain, malt and protein yield for two rowed barley variety BH 885. The thermal utilization by the crop *viz.* GDD, PTU and HTU was significantly higher with 105 kg N/ha as compared to lower nitrogen levels while the seed rate and row spacing could not significant influence these parameters. Dry matter accumulation, LAI, number of tillers, grain, malt and protein yield had positive and strong correlation with agro-meteorological indices.

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