Bangladesh J. Bot. **54**(2): 221-231, 2025 (June) DOI: https://doi.org/10.3329/bjb.v54i2.81651

EFFECTS OF SOWING ENVIRONMENTS AND N-LEVELS ON DRY MATTER PARTITIONING AND PHENOLOGICAL STAGES IN WHEAT VARIETIES OF N-W HIMALAYAS, INDIA

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Keywords: Wheat, Biomass partitioning, Reproductive phase, Grain yield, N-W Himalayas

Abstract

The study was conducted in *rabi* seasons of 2015-16 and 2016-17 to explore the potential of different wheat varieties under changing climatic scenario which is prevalent during grain filling/reproductive stages. The wheat crop was sown under different sowing environments (early, normal and late) with three nitrogen levels (100, 125 and 150 kg/ha). The variety WH 1105 was found to be the best in all the sowing environments, and early sown conditions were observed best with higher dose of nitrogen (150 kg/ha) under irrigated conditions. There was a positive relationship between total dry matter production at anthesis and grain yield of wheat (R^2=85) irrespective of varieties, sowing environments and nitrogen levels.

Introduction

Wheat is the 2nd staple food crop of India and is cultivated on 304.69 lakh hectares with the production and productivity of 106.84 million tonnes and 3507 kg/ha, respectively (Anonymous 2023). The demand for increasing wheat production is urgent, because the population of wheat producing countries will require about 40-50% more wheat by 2035. Obtaining higher grain yield to feed the growing population is always a need of hour and a challenge for agricultural scientists all over the world especially under the changing climatic conditions. By 2050, there will be about 20-30% wheat yield losses in developing countries as a result of predicted temperature increase of 2-3^{o}C (CIMMYT and ICARDA 2011). Selection of improved varieties and optimum sowing time play a remarkable role in exploiting the yield potential of the crop under particular agro climatic condition. The accumulated temperature is also considered as the principal factor which affects the year-to-year variation in development of various phenophases (Gupta *et al.* 2020a). Grain yield is a function of biomass accumulation from flowering to physiological maturity and the amount of biomass accumulated before flowering and translocated to the grains during grain filling (Gupta *et al.* 2023b). Planting time of wheat can be so adjusted that the various physiological stages of the crop can coincide with specific temperature during crop growth cycle (Keerthi *et al*. 2017).

Advance or delay in sowing date, increasing N application and choice of suitable variety with the best thermal requirement represent the main agronomic manipulations which help to maintain existing crop production levels (Gupta *et al.* 2021a, Gupta *et al*. 2020b). In many wheat growing areas in India, wheat experiences 35^{o}C during grain development which reduces the yield and also affects the partioning of dry matter/assimilates to various vegetative and reproductive parts of wheat at different growth stages. In Northern hills, 2nd fortnight of March adjudged to be the most important time as during this period the temperature above normal caused a reduction in partioning of dry matter towards reproductive parts (ear) and ultimately reduces wheat productivity (Sandhu *et al*. 2016).

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To cope up with these climatic changes, it is very necessary to adjust the sowing time so as to prevent the early occurrence of the reproductive stages which are in vogue due to changing climatic conditions. Hence, the study was planned with the following objectives: (1) to assess the changes in duration of phenophases wheat varieties under varying sowing environments and N-levels; (2) to study the effect of sowing environments and N-levels on biomass partioning at different phenological stages of wheat varieties.

Materials and Methods

Field experiments were conducted to investigate the impact of sowing environments (25th October, 14th November and 04th December) and N-levels (100, 125 and 150 kg/ha) on occurrence of various phenological stages, stage-wise dry matter accumulation and partioning of wheat varieties. The experiment consisted of three wheat varieties namely HD 2967 (V_1), RSP 561 (V_2) and WH 1105 (V_3) which were planted in three sowing environments 25th October (D_1-early), 14th November (D_2-normal) and 4th December (D_3-late) with three nitrogen levels (N_1-100, N_2-125 and N_3-150 kg/ha). The experiments were conducted at Research Farm of Agrometeorology section, SKUAST-Jammu in low altitude of N-W Himalayas under irrigated conditions in *rabi* 2015-16 and 2016-17 (Latitude $32^0 39^/$ N, longitude $74^0 58^/$ E and 332 m above mean sea level) in split plot design using three replications. Wheat varieties were allotted to main plots, sowing environments to sub plots, while N-levels were allotted to sub-sub plots. Entire quantity of phosphorus + potash and half quantity of nitrogen were applied at sowing time; remaining dose of nitrogen was applied in two equal doses at 25-30 days after sowing (DAS) coinciding with CRI stage and just before boot initiation. The weather data (temperature) for *rabi* 2015-16 and 2016-17 was recorded at Agrometerological Observatory of SKUAST-Jammu situated at about 50 m from the experimental site (Fig. 1).

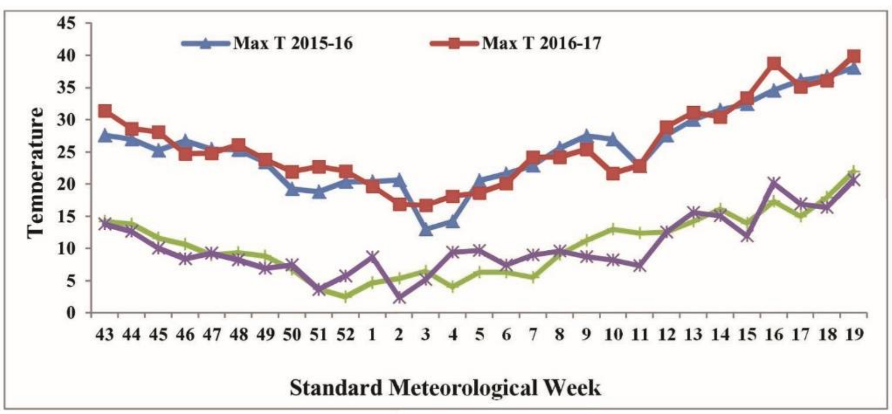

Fig. 1. Temperature data of 2 years during the cropping seasons.

The soil of the experimental site was sandy clay loam in texture, slightly alkaline, low in organic carbon and available nitrogen but medium in available phosphorus and potassium with electrical conductivity in the safer range. The area represents the low altitude sub-tropical in nature characterized by hot and dry summers from April to June, followed by hot and humid conditions from July to September (*monsoon*), cold winters from November to January and mild climate during February and March.

Data for total dry matter accumulation recorded on all the phenological stages of wheat; whereas, leaf and stem dry matter *i.e.*, partioning of dry matter was done at tillering, flag leaf, anthesis and physiological maturity stages. The partioning of dry matter into reproductive parts was done at grain development stages *viz.*, anthesis, milking, dough and physiological maturity stages. At each growth stages, 0.5 m row length within each treatment were harvested; leaves, stem and reproductive parts (ears) were separated, sun-dried in paper bags for 2-3 days and then in an electric oven for at about 65°C till a constant weight was obtained.

Results and Discussion

The total dry matter production (TDM) was significantly influenced by varieties, sowing environments and N-levels at different phenological stages. Initially, a gradual increase in dry matter accumulation of the plants was observed as recorded at crown root initiation (CRI) and tillering stage which picked up quickly at the later phenological stages (Tables 1-2).

Differences in dry matter accumulation due to wheat varieties were statistically significant at all the phenological stages except at CRI stage. WH 1105 variety accumulated significantly higher dry matter right from tillering to physiological maturity stage. However, variety RSP 561 accumulated significantly lowest dry matter at all the phenophases; but the values were at par with HD 2967 variety at all the stages. Statistical significant variation in dry matter among the varieties might be due to the genetic variation and capacity of producing dry matter at different phenological stages and might also be due to the fact that they belong to different or same species and their interaction with environment due to their inherent genetic makeup (Jat and Singhi 2004).

The crop sown on 25th October (early sowing) recorded significantly higher total dry matter at all the phenological stages as compared to the crop grown on 14th November and 4th December. Whereas, the values observed for dry matter production for normal and late sowing were also significantly different. Higher dry matter production in early sowing of wheat was due to the advantage of favourable environmental conditions and also during early sowing; fertilizer use efficiency was more as compared to the later sowings (Kaur *et al.* 2010).

The higher TDM under increased N levels may be due to increased cell division and cell expansion with the increased N availability and thus owes to higher amount of N, which increased the nutritional environment and hence forth increased the meristematic activity of the plant resulting in more accumulation of dry matter (Kachroo and Razdan 2006).

During the reproductive stage, ear dry matter was significantly affected by varieties, sowing environments and nitrogen levels. (Figs 2, 3 and 4). Among varieties, significantly higher ear dry matter recorded with WH 1105 and the minimum observed in RSP 561 variety at anthesis, milking, hard dough and physiological maturity stages.

Among the sowing environments, significantly higher ear dry matter at various sub stages of reproductive period recorded with early sowing (25th October) followed by 14th November sowing, whereas, the minimum reproductive parts dry matter registered in late sowing (04th December). A significant difference in partitioning of dry matter to different plant parts under different sowing environments could be attributed to the fact that earlier sown crop (25th October) faced favourable conditions during vegetative and reproductive phase, while delayed sown crop (14th November and 4th December) faced low temperature at the time of emergence as well as comparatively warmer environment at anthesis stage. Similar findings were recorded by Kumar *et al.* (2013) and Keerthi *et al.* (2017).

Table 1. Total Drymatter accumulation (g/m^2) of wheat varieties at different phenological stages as affected by sowing environments and nitrogen levels.

Treatments	Phenological stages								
	CRI	Tillering	Jointing	Flag leaf	Head emergence	Anthesis	Milking	Hard dough	Physiological maturity
Varieties									
V_1: HD 2967	50.3	63.4	260.2	483.7	616.5	845.1	1018.6	1063.6	1104.9
V_2: RSP 561	49.1	65.5	241.6	446.4	568.3	765.6	956.1	1023.3	1086.7
V_3; WH 1105	58.5	75.6	335.7	613.5	760.7	922.8	1087.8	1132.1	1177.1
CD (5%)	4.2	5.8	37.4	58.1	67.2	84.7	60.2	55.3	38.9
Sowing environments									
D_1: 25th October	53.5	70.6	286.3	569.9	724.0	1002.9	1150.3	1215.8	1243.6
D_2: 14th November	53.0	68.6	280.6	530.4	684.2	861.5	1023.1	1068.4	1130.9
D_3: 04th December	51.4	65.3	270.6	443.3	537.3	669.2	889.1	934.7	994.2
CD (5%)	0.45	2.4	4.6	30.9	35.7	78.4	45.7	84.2	90.5
Nitrogen levels									
N_1: 100% RDN (100 kg N/ha)	47.2	61.5	251.6	460.1	562.9	785.4	949.0	1011.0	1061.5
N_2: 125% RDN (125 kg N/ha)	54.9	69.3	285.4	528.6	676.2	857.2	1042.9	1092.2	1136.0
N_3: 150% RDN (150 kg N/ha)	55.8	73.7	300.4	555.0	706.4	890.9	1070.6	1115.8	1171.1
CD (5%)	2.1	5.4	20.6	32.7	28.4	30.9	26.3	21.5	32.6

CRI=Crown root initiation.

Table 2. Leaf and stem drymatter accumulation (g/m^2) of wheat varieties at different phenological stages as affected by sowing environments and nitrogen levels (pooled data of 2 years).

Treatments	Leaf dry matter				Stem dry matter			
	Phenological stages							
	Tillering	Flag leaf	Anthesis	Physiological maturity	Tillering	Flag leaf	Anthesis	Physiological maturity
Varieties								
V_1: HD 2967	45.29	162.79	149.78	126.35	16.49	318.42	444.96	370.79
V_2: RSP 561	44.60	158.90	152.32	132.99	18.49	286.92	421.60	379.22
V_3; WH 1105	51.84	201.38	171.31	142.27	18.89	403.29	496.09	397.28
CD (5%)	1.5	6.3	8.4	10.2	2.1	39.6	40.1	17.5
Sowing environments								
D_1: 25th October	49.36	197.26	176.46	163.76	19.82	362.52	519.74	413.56
D_2: 14th November	46.89	175.64	154.72	130.90	18.24	351.88	465.66	386.41
D_3: 04th December	45.48	150.17	142.23	106.96	15.81	294.23	377.25	347.32
CD (5%)	3.4	17.3	10.5	39.1	2.5	10.2	45.6	42.4
Nitrogen levels								
N_1: 100% RDN (100 kg N/ha)	42.33	160.98	147.48	122.33	17.12	297.90	423.54	356.82
N_2: 125% RDN (125 kg N/ha)	47.71	178.52	161.70	136.55	18.16	347.32	459.48	386.17
N_3: 150% RDN (150 kg N/ha)	51.69	183.57	164.23	143.73	18.59	363.42	479.64	404.29
CD (5%)	3.5	6.7	4.6	6.5	2.5	16.8	22.9	35.4

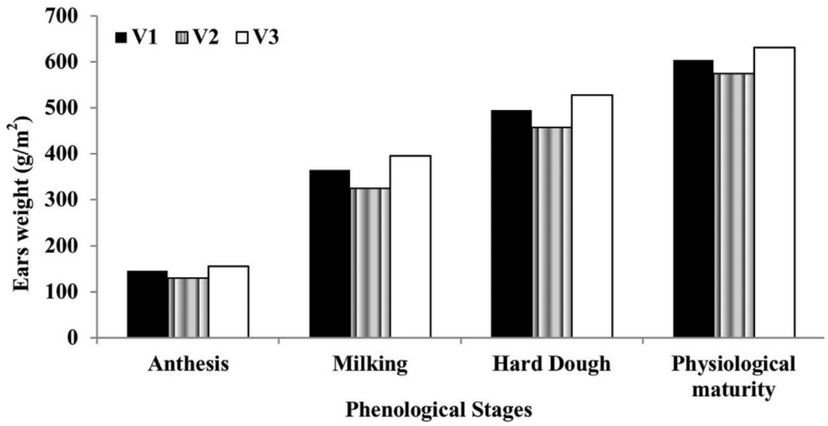

Fig. 2. Ears drymatter accumulation (g/m^2) of wheat varieties at various phenological stages as affected by sowing environments and N-levels (pooled data of 2 years).

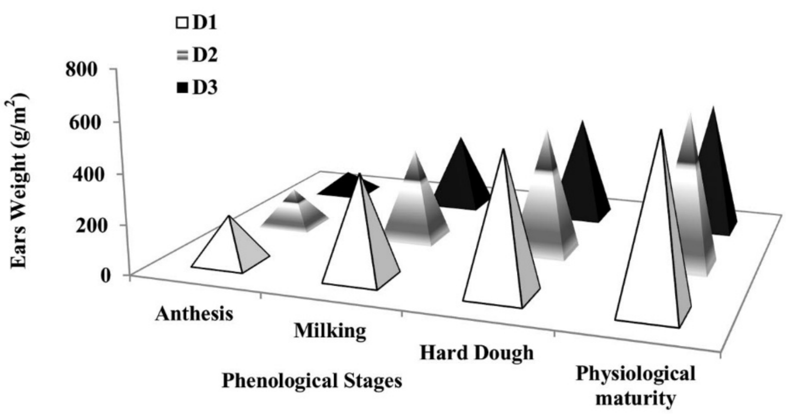

Fig. 3. Ears drymatter accumulation (g/m^2) at various sowing environments in different phenological stages as affected by varieties and N-levels in wheat (pooled data of 2 years).

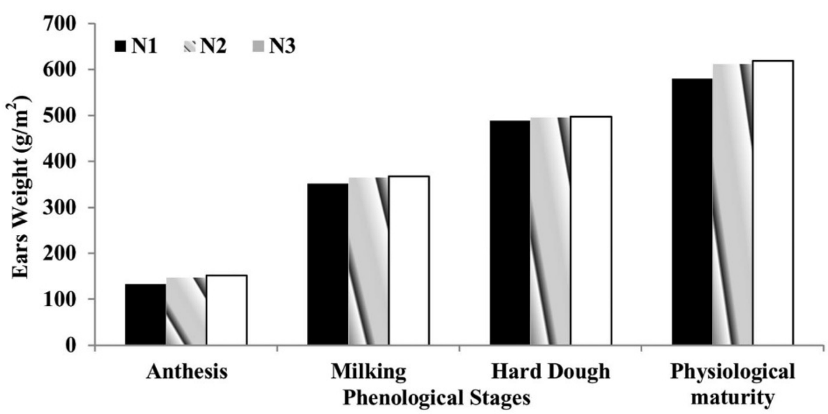

Fig. 4. Ears drymatter accumulation (g/m^2) by N-levels at various phenological stages as affected by wheat varieties and sowing environments (pooled data of 2 years).

The increase in nitrogen dose increased the dry matter partioning significantly up to 125 kg N/ha at all phenological stages. Significantly lower dry matter partitioning was recorded in 100 kg N/ha. Lesser growth in lower nitrogen levels treatment may be due to low availability of plant nutrients which are necessary for the normal growth as compared to 125 and 150 kg N/ha. Nitrogen being the basic constituent of chlorophyll, protein and cellulose required for photosynthesis and tissue formation for proper growth (Keerthi *et al.* 2017).

The variety WH 1105 took more days to attain the grain development phases like anthesis, milking, hard dough and physiological maturity in both the years under study as compared to HD 2967 and RSP 561 varieties (Fig. 5). The time duration taken by a particular variety to accomplish reproductive phenophase might be due to the response of that particular variety to the air and canopy temperature during grain development period. It also mainly depends upon the non-adoptability of that variety to higher temperature which again depends on its genetic makeup and tolerance limit to the range of temperature at the grain development period (Suleiman *et al.* 2014).

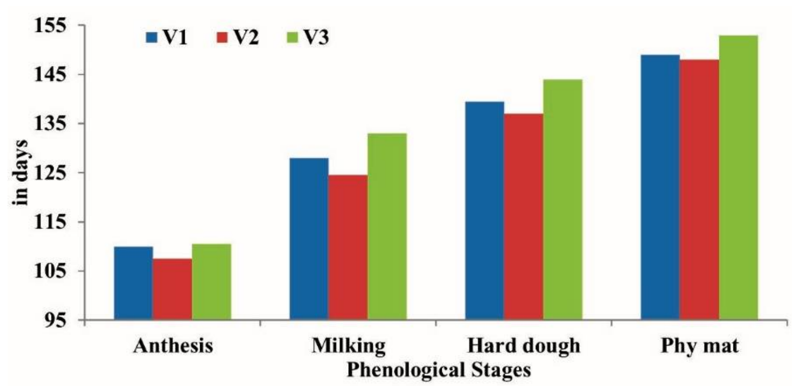

Fig. 5. Changes in duration (days) of physiological stages of wheat varieties as affected by sowing environments and N-levels (pooled data of 2 years).

Higher number of days to achieve phenophases anthesis, milking, hard dough and physiological maturity recorded in early sowing (25th October) followed by normal (14th November) and late (4th December) sowings (Fig. 6). Wheat sown on 25th October took more days for grain development phases as the crop sown under early conditions had more number of days for grain filling period. On its contrary, anthesis, milking, dough stage started earlier with the delay in sowing and thus late sown crop took significantly less number of days to complete these stages (Hossain *et al.* 2012). The stages like anthesis, milking, dough and physiological maturity were accomplished earlier in normal and late sown wheat crop because of higher maximum, minimum and mean temperature during these phenological stages. It also might be due to the reason that early sown crop has vigorous vegetative growth which resulted in delayed accomplishment of these stages. Amravat *et al.* (2013) also inferred that early sown wheat crop took maximum calendar days to attain different phenological stages till maturity which reduced significantly with subsequent delay in sowing time.

Due to N-levels, numerical higher values of days to achieve various phenological stages was recorded in higher level of nitrogen *i.e.*, 150 kg/ha which was followed by 125 and 100 kg N/ha both in first and second years of cropping (Fig. 7). Enhanced N-level (150 kg/ha) registered numerically higher values of days to achieve the phenological stages like anthesis, milking, hard dough and physiological maturity which was followed by 125 and 100 kg N/ha. Kaur *et al.* (2016) also observed more number of days to complete one stage to another in 150% RDF treatment. It might also be due to the maximum uptake of nutrients at the time of tillering, which had prolonged the vegetative growth of the crop and thus led to higher days to complete grain development period.

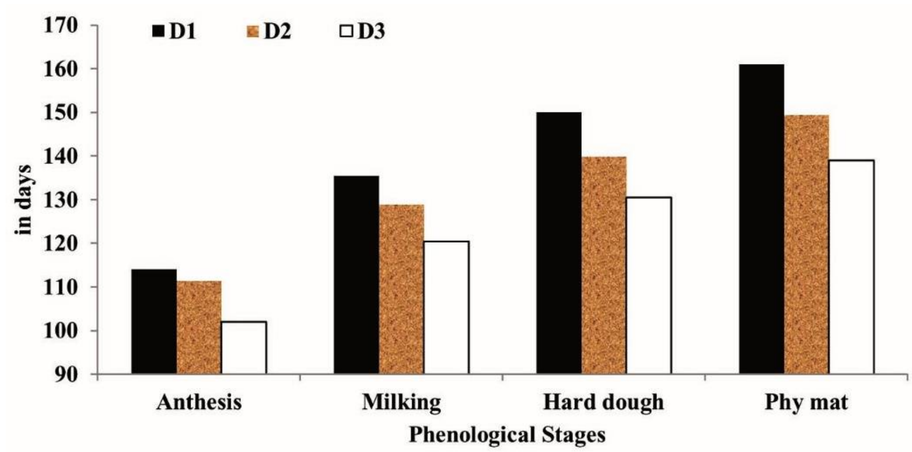

Fig. 6. Changes in duration of physiological stages of wheat crop sown at different sowing environments as affected by varieties and N-levels (pooled data of 2 years).

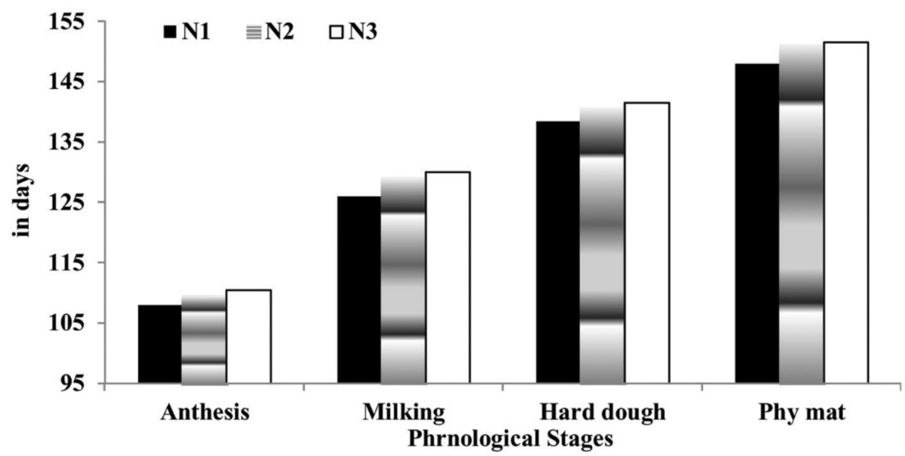

Fig. 7. Changes in duration of various physiological stages of wheat crop due to N-levels as affected by different sowing environments and varieties (pooled data of 2 years).

The relationship between grain yield of wheat and biomass at anthesis was highly significant (R^2= 85); the higher value of R^2 denotes a close and relevant relationship between the both factors. The highly significant relationship also denotes that a major proportion of biomass accumulated at anthesis add its maximum portion to the grain yield (Fig. 8). The higher partitioning of dry matter accumulated during anthesis towards the grains indicated the more translocation of assimilates during flowering and grain filling stage towards the grain yield irrespective of varieties, sowing environments and nitrogen levels resulting in higher grain yield (Amanullah and Inamullah 2016).

Grain yield of wheat was significantly influenced by varieties, sowing environments and nitrogen levels in both the crop growing seasons (Table 3). Among the varieties, WH 1105 recorded significantly higher grain yield as compared to the other two varieties. However, varieties HD 2967 and RSP 561 were statistically at par during both the years of experimentation. Similar trend was noticed for straw and biological yield of wheat crop.

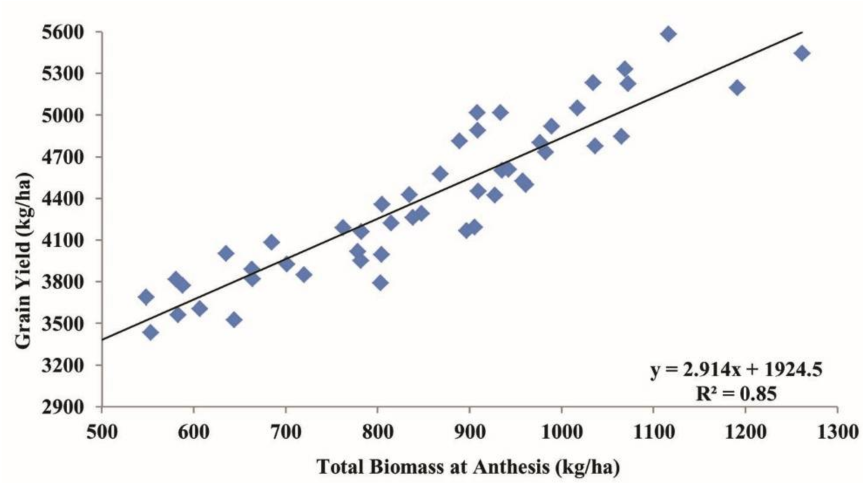

Fig. 8. Relationship between total dry matter at anthesis and grain yield of wheat (pooled data of 2 years).

Table 3. Performance of different wheat varieties as affected by various sowing environments and N-levels.

Treatments	Grain yield (kg/ha)		Straw yield (kg/ha)		Biological yield		Harvest index (%)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Varieties								
V_1: HD 2967	4160	4395	5858	6378	10017	10773	41.5	40.8
V_2: RSP 561	3975	4255	5923	6488	9898	10743	40.2	39.6
V_3: WH 1105	4573	4617	6271	6748	10844	11365	42.1	40.5
SEM (±)	85	47	84	72	127	86	0.54	0.3
CD (5 %)	332	184	329	281	501	338	NS	NS
Sowing Environments								
D_1: 25th October	4707	4857	6614	7272	11321	12130	41.5	40.0
D_2: 14th November	4313	4649	5959	6696	10272	11346	42.0	41.0
D_3: 04th December	3687	3759	5479	5645	9166	9405	40.3	40.0
SEM (±)	66	59	84	82	112	129	0.44	0.25
CD (5 %)	202	182	258	254	345	397	1.36	0.78
Nitrogen levels								
N_1: 100 % RDN (100 kg N/ha)	3955	4179	5652	6263	9607	10441	41.1	40.0
N_2: 125 % RDN (125 kg N/ha)	4313	4471	6103	6605	10416	11076	41.3	40.4
N_3: 150 % RDN (150 kg N/ha)	4440	4616	6297	6747	10737	11363	41.3	40.6
SEM (±)	47	49	70	55	86	90	0.35	0.24
CD (5 %)	135	141	201	156	248	259	NS	NS

Grain yield of wheat crop was affected to a great extent due to different sowing environments. Delayed sowing adversely affected the yield of wheat crop. Significantly higher grain yield observed in early sown conditions (25th October) and followed by statistically lower values registered with normal and late sowings in both the seasons. These two latter sowing environments also differed statistically significant from each other. Normal and late sown wheat recorded about 9.1 and 27.6% less grain yield, respectively than early sown crop. Similar % trend was noticed for straw and biological yield of wheat crop.

Wheat crop when applied 150% RN (150 kg/ha) performed the highest grain yields in both the years of experimentation but the values were at par with that of 125% recommended nitrogen (125 kg/ha). Recommended dose of nitrogen (100 kg/ha) also performed well but the values were significantly lower to other two doses of nitrogen. Similar trend was observed for straw and biological yields of wheat crop.

From the data, it can be inferred that among the wheat varieties, the values of harvest index were statistically non-significant. Whereas, in various sowing environments; wheat crop sown on 14th November recorded higher values of harvest index but were statistically at par to the values recorded with earlier sown wheat. Different N-levels also had non-significant effect on harvest index of wheat crop. However, numerically higher values of harvest index observed in 150 kg N/ha which was followed by the values recorded in 125 and 100 kg N/ha.

The higher grain, straw and biological yields of wheat could be attributed to greater genetic potential with efficient utilization of radiation by leading to production of maximum leaf area and dry matter which in turn results into higher yields (Gupta *et al.* 2022a). Variety WH 1105 performed significantly superior to HD 2967 at various locations as reported in the report of AICWBIP (Tiwari *et al.* 2016).

The availability of optimum environmental conditions for growth and development of crop in early sowing might have enhanced accumulation of photosynthates from source to sink and could have resulted in higher yield values (Ram *et al.* 2012, Gupta *et al.* 2021b, Gupta and Gupta 2022). Higher wheat yield in enhanced N levels (125 kg/ha) could be traced to adequately N fertilized crop benefitted from higher rates of N nutrition that might have resulted into more vigorous and extensive root system of crop leading to increased vegetative growth means for more sink formation and greater sink size, greater carbohydrate translocation from vegetative growth (Gupta *et al.* 2023a). Decline in HI in later sowings as compared to early sowing might be due to higher temperature during reproductive stages in normal and late sowings (Dhyani 2010).

Wheat variety WH 1105 recorded significantly higher dry matter accumulation and its partitioning and yield over HD 2967 and RSP 561 varieties. Among sowing environments, 25th October sown wheat crop registered significantly higher values of TDM, grain and straw yield followed by normal and late sowing environments. Delayed sowing of wheat lessens the reproductive stage which was mainly due to higher temperature during the reproductive/grain filling stages. Dry matter was partitioned towards leaves in the initial/vegetative stage, thereafter stem and after anthesis it was routed towards economic parts though ears' production.

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(Manuscript received on 22 November, 2023; revised on 04 May, 2025)