Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 3096-3101
Received: 19-07-2018
Accepted: 20-08-2018

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To find out sensitive crop growth stages of wheat crop of weather in Raipur condition

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Abstract
The present investigation entitled "To find out sensitive crop growth stages of wheat crop of weather in Raipur condition" was carried out during *Rabi* seasons of 2015-16 at Research and Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur Raipur to examine to validate the results of crop weather relationship of different wheat varieties grown under different growing environments rice based cropping system. The treatment combinations of three sowing dates (15 November, 30 November, 15 and December) and three varieties (Kanchan, HD-2967, and CG-1013) were laid out in a randomized block design with three replication.

The Phenological events such as CRI, tillering, ear emergence, 50 percent flowering, milking, dough and maturity stages decreased appreciably with delay in sowing. However, days for these phenological events varied from variety to variety due to their response to different environments.

In minimum temperature was no significant effect on CRI stage, EMR, 50% flowering and maturity stages but other stages like tillering, milk and dough stages are significant on minimum temperature during crop cultivars.

Maximum temperature during all stages significantly and adversely influenced the grain yield of kanchan variety of wheat (except the Max-T at maturity of kanchan). The negative significance of the adverse effect of maximum temperature on yield of wheat kanchan variety (based on probability values associated with *t* statistics) was highest during 50% flowering stage and it was followed by milk stage. The highest significant effect of rainfall was observed during 50% flowering. Rainfall at crucial phases of CR, tillering, emergence, 50% floweing, milking and dough stages is helping to meet the crop water requirement which includes maintaining soil moisture status and evapo-transpirational losses.

Keywords: Temperature, Rainfall, growth stages, phonological stages

Introduction
Wheat is the most widely cultivated food grain crop of the world. It is grown not only in temperate zones but also in tropical and sub-tropical zones. In India, wheat is the second important staple food crop, rice being the first. It has wide adaptability and can tolerate severe cold also. The best quality wheat is produced with cool and moist weather during the vegetative phase followed by dry warm weather during reproductive phase.

Wheat is a long day plant. Temperature ranging between 20º to 25 ºC is ideal for seed sowing and germination. Whereas the optimum temperature for vegetative growth ranges from 16º to 22 ºC. During the grain development wheat requires a mean maximum temperature of about 25 ºC for at least 4-5 weeks. Wheat is grown well in those areas where annual rainfall ranges between 1200 mm to 1600 mm. Winter wheat generally completes its life-cycle most rapidly when grown in low temperatures during the early stages of growth but high temperature is required during the later stages of growth.

In world, wheat is grown in an area of 296 million hectares and production of 935 million tonnes (FAO 2013)**.** Wheat serves as a staple food for about one billion people in as many as 46 countries of the world. China has ranked first in area and production of wheat, followed by India, but UK ranked first in productivity followed by France. Three main species commonly grown in the world including India are the common wheat (*Triticum aestivum* L.), the macaroni or durum wheat (*Triticum durum*) and the emmer wheat (*Triticum dicoccum*). Out of these species maximum area is under *Triticum aestium.* In India, more than 80 percent of the total wheat area is under this species, whereas the area under Marconi and emmer wheat is only 12 percent and 1 percent, respectively.

The productivity of wheat is largely dependent on the magnitude of temperature change. 1ºC increase in temperature throughout the growing seasons will have no effect or slight increase on productivity in north India. But an increase of 2 ºC temperature reduced potential grain yield at most of the places (Agrawal and Sinha, 1993) [1].

All India Co-coordinated Wheat Improvement Project released many wheat varieties suited for normal and delayed sowing conditions for different states. Short duration varieties like LOK-1, GW-273 and WH-147 are found suitable for Chhattisgarh state. Lot of work has been done on date of sowing in India. However very little work has been done in Chhattisgarh on the effect of weather parameters particularly for effect of temperature during crop growing season and various phenophases of the crop.

Material and Methods

Location of Experimental site

The experiment was set at Research and Instructional farm of Indira Gandhi Krishi Vishwavidyalaya; Raipur situated in Eastern Central part of Chhattisgarh at latitude of 21^0 16' N, longitudes 81^0 36'E and altitude 289.5 m above mean sea level. The present experiment was conducted during Rabi seasons of 2015-16.

Climate

The climatic condition of Chhattisgarh plains zone is tropical wet and dry climate with mean annual rainfall 1249 mm out of which 87% is received during monsoon (June to September). Rest of the 13% rainfall is received during winter season (December to February) and hence wheat is mostly grown under irrigated conditions. Maximum and minimum averege temperature is 32.65 ^{0}C and 20.88 ^{0}C during the year. Atmospheric humidity is normally higher during June to September and thereafter, during Rabi with increased sunshine hours.

Weather conditions during crop period

During the crop growth period the maximum temperature ranged from 22 to 40 ^{0}C, whereas minimum temperature ranged from 5.4 to 24 ^{0}C. The total rainfall recorded was 19.6 mm, morning relative humidity varied from 96 to 49 percent, whereas in afternoon it varied from 66 to 10 percent. The wind speed ranged from 1.4 to 6.4 kmph during the crop growth period, the evaporation of 1 to 8.9 mm/day was recorded, the bright sunshine hours varifed from 0.4 to 10.2 hrs/day. The weather parameters recorded at Agrometeorology observatory I.G.K.V. Raipur, during the crop season are presented in Table 1 and depicted through figure 1.

Table 1: Weekly meteorological data during crop growth period (from 46 SMW to 13 SMW)

Wk No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Rain-Fall (mm)	Relative Humidity (%)		Wind Velocity (Kmph)	Evapo-ration (mm)	Sun Shine (hours)
					I	II			
46	12-18	31.7	16.3	0.0	89	33	2.4	3.3	7.5
47	19-25	30.6	15.5	0.0	88	36	2.8	3.3	8.3
48	26-02	31.9	16.7	0.0	87	34	2.4	3.3	7.5
49	Dec 03-09	31.2	14.8	0.0	88	31	2.3	3.0	8.0
50	10-16	30.1	17.3	4.4	77	46	2.9	2.7	4.4
51	17-23	27.7	16.6	9.4	85	52	3.1	2.3	2
52	24-31	26.9	10.8	0.0	87	29	2.4	2.6	6.2
1	Jan 01-07	30.5	12.1	0.0	82	27	2.0	2.9	7.9
2	08-14	29.3	11.1	0.0	87	27	2.5	3.1	7.5
3	15-21	27.6	14.0	2.0	88	46	3.4	2.5	4.3
4	22-28	27.0	9.0	0.0	90	33	2.6	3	8.7
5	29-04	31.9	14.3	0.0	84	32	2.6	3.6	9.0
6	Feb 05-11	31.1	14.0	0.0	78	32	2.9	4.2	8.9
7	12-18	32.6	19.2	0.0	81	39	3.2	3.7	5.2
8	19-25	34.9	19.3	0.0	69	30	3.1	4.6	6.9
9	26-04	33.6	20.8	0.0	81	37	3.3	4.1	3.8
10	Mar 05-11	35.4	20.2	0.6	73	27	4.3	5.5	7.4
11	12-18	34.6	21.3	2.9	75	38	4.8	5.4	7.4
12	19-25	37.8	19.6	0.0	59	14	4.3	7.6	9.3
13	26-01	37.5	21.7	0.0	69	25	4.1	6.4	8.2

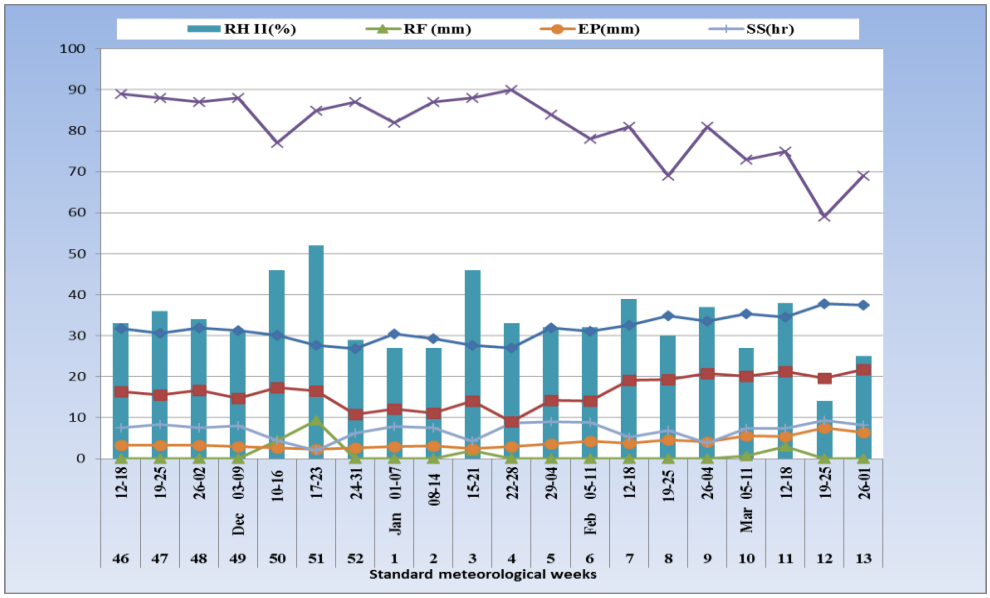

Fig 1

Soil
The soil of the experimental field was sandy loam with moderately course texture of inceptisol group locally known as "Matasi." The soil was netural in reaction and had low phosphorus and medium nitrogen and potassium content.

Cropping history of the field
Prior to the present experiment, the field was cropped with rice (*Oryza sativa* L.) during *kharif* and wheat (*Triticum aestivum* L.) during *Rabi* in the preceding three years.

Experimental Detail
The experimental was laid out in randomized block design (factorial) considering 9 treatments of two factors (3 dates of sowing and 3 varieties) repeated three times. The details are given below and layout is shown in fig. 2.

Experimental design	:	Factorial RBD
Treatments	:	9
Date of sowing (3)	:	D_1 - 15/11/2015 D_2 - 30/11/2015 D_3 - 15/12/2015
Net cropping area	:	1240.8 m^2
Replication	:	3
Total No. of plots	:	27
Plot size	:	4.4×7.8 (34.32m^2)
Season	:	Rabi
Crop	:	Wheat
Varieties (3)	:	V_1 – KANCHAN V_2 - HD2967 (National check) V_3 – CG GENHU1013
Seed rate (kg/ha)	:	125
Fertilizer dose (kg/ha)	:	100:60:40. N: P_2O_5:K_2O

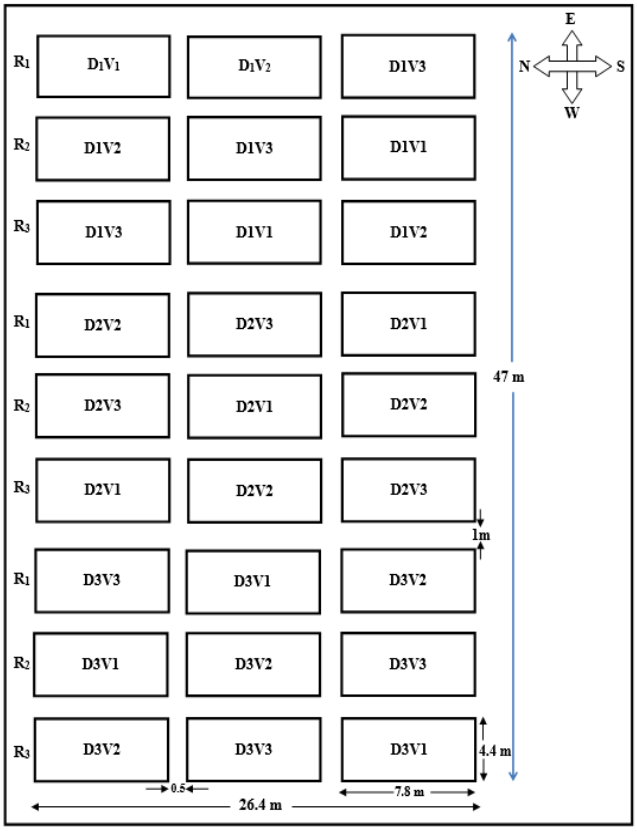

Fig 2: Layout of the experiment field

Calendar of operations
Field preparation
After the harvest of paddy crop the field was allowed to dry, till the optimum moisture is achieved, than the field was ploughed twice with tractor drawn cultivator. Harrowing was done to break the clods and to make the field pulverized and well levelled. After that lay out was done and plots were marked with the help
Fir 3.2 Layout the experiment

Calendar of operations
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Sowing
For sowing furrows were opened with the help of ''kudali" by labours and seeds were sown in furrows at 20 cm apart rows @125 kg/ha. Before sowing, seeds were treated with Thiram @ 3g/kg seed.

Nutrient application
Nutrients were applied uniformly to the crop as per the recommendations. i.e., 100 kg N, 60 kg P_2O_5, 40 kg K_2O / ha. One third of N and full quantity of P_2O_5 and K_2O were applied before sowing as basal. The half of the remaining quantity of nitrogen was applied at the crown root initiation stage and remaining half was given at ear head initiation stage.

Irrigation
Six irrigations (excluding rainfall) were given to the crop for proper growth and development from sowing to maturity. Come up irrigation was given just after sowing and the rest five irrigations were given at CRI, tillering, late jointing, flowering and dough stages, respectively.

Weed Management
Lambs quarters (*Chenopodium album* L.) white sweet clover (*Melilotus alba* L.) and Black medic (*Medicago denticulate* L.) were predominantly observed in the experimental field. The weeds were suitably controlled by spraying of 2, 4-D herbicide @ 0.75 kg a.i. /ha as post emergence at 30-35 days after sowing.

Harvesting and threshing
The crop was harvested on different dates as per maturity of the respective varieties. Before harvesting one row on each side and half meter on either side was removed as border. Before threshing the produce was sun dried and plot wise total biomass weight were taken. Threshing was done by beating the produce with bamboo sticks followed by winnowing manually for cleaning of grains. The weights of cleaned grains of each plot were recorded.

Harvesting dates			
Variety	**D_1-15 November**	**D_2-30 November**	**D_3-15 December**
Kanchan	08/03/2016	14/03/2016	25/03/2016
HD-2967 (National check)	15/03/2016	20/03/2016	30/03/2016
CG-1013	12/03/2016	17/3/2016	26/03/2016

Observations

Pre harvest observation

Phenological observations

The dates of occurrence of different phenological stages *viz.*, emergence, crown root initiation, tillering, ear emergence, 50 percent flowering, milking, dough and maturity were observed visually and noted.

Plant height

Height of 5 randomly selected plants from each plot were taken at 15 days intervals starting from 30 days after sowing (DAS) till maturity. The plant height was measured from base of the plant to tip of the longest leaf (these plant were uprooted and used for dry matter production) the mean height was worked out by dividing the summation by five.

Number of tillers/plant

The numbers of tillers per plant were counted taken at randomly in each plot. Tillers were counted at an interval of 15 days up to maturity.

The total numbers of tillers from 5 plants were counted at maturity. The mean tillers per plant were determined by dividing the summation by five. The ear bearing tillers (effective) were also counted after completion of flowering at 90 days after sowing.

Dry matter production

The dry matter production was recorded at 15 days interval from 30 DAS to maturity by selecting 5 plants each time and average dry matter production per plants was workout. This was multiplied by the average number of plants/m^2 to obtain the dry matter production/m^2.

Post harvest observations

Number of ear heads per m2

Number of ear heads were counted before harvesting from 3 randomly plots of 1 m2 earlier fixed to record plant population, then averaged.

Length of ear head

Length of 10 ear heads randomly selected in each plot was measured from base to tip of ear head excluding awns and then averaged.

No. of grains per ear head

The ear heads used to measure the length were threshed and number of grains were counted and averaged.

Grain and Straw yield

The crop from each net plot was harvested and tied. The total biomass weight (grain and straw) was obtained by weighing the bundles after proper sun drying. The grain from each bundle was threshed out and the weights of cleaned grains were noted. The straw yield was obtained by subtracting the grain yield from the total biomass of respective treatments.

Heat units

Heat Use Efficiency (HUE)

Heat Use Efficiency (HUE) for total dry matter was obtained as under

$$\text{HUE } (g/m^2 / {}^0\text{day}) = \frac{\text{Biomass } (g / m^2)}{\text{GDD } ({}^0\text{days})}$$

Radiation Use Efficiency (RUE)

RUE ($gMJ^{-1\ day-1}$) = Biomass (g / m^2) / Radiation intercepted (M J/m^2/day)

Results and Discussions

In Chhattisgarh wheat is mostly grown under irrigated condition in command area and in tube well irrigated areas. The productivity of this crop is low as compared to national average, because of delayed sowing in rice based cropping system, shorter winter span and higher temperature during grain filling and maturity stages. With this background the present experiment was conducted during winter season of 2015-16 to identify suitable high yielding varieties of wheat grown in different growing environments and suitability in late sown conditions. This will help identifying wheat varieties which can tolerate the high temperatures during reproductive and grain filling stages.

Weather parameters during growth stages

Temperature during growth stages

Data regarding maximum, minimum and mean temperature during different phenological stages under different thermal environment and genotypes are summarized in table 2. Data presented in Table 2 reveals that for wheat variety Kanchan during crop growth period experienced the difference in temperature at maturity stage from D_1 to D_3 for Kanchan was 0.5 ^{0}C in maximum temperature, 0.2 ^{0}C in minimum temperature and 0.4 ^{0}C in mean temperature. Wheat variety HD-2967 sown on 15 November, 2015 showed that the difference in temperatures during maturity stage for variety HD-2967 was 1.2 ^{0}C in maximum temp., 0.8 ^{0}C in minimum temperature and 1 ^{0}C in mean temperature from D_1 to D_3. The difference in temperature from D_1 to D_3 for variety CG-1013 was 1 ^{0}C in maximum temp., 0.6 ^{0}C in minimum temperature and 0.8 ^{0}C in mean temperature. In general the maximum, minimum as well as mean temperature was higher when the crop was sown in timely sowing condition closely followed by early sown and late sown condition during sowing to emergence. During emergence to CRI stage the maximum temperature, minimum temperature and mean temperature was higher during early sown condition which gradually decreased when the sowing was delayed. The maximum, minimum as well as mean temperature increased gradually when the sowing was delayed from 15 November (D_1) during sowing-emergence phase and later increasing putting the crop under thermal stress in D_3 (15 December) sowing.

Table 2: Maximum, minimum and mean temperatures (^{0}C) during different phenology of wheat varieties

DAS	Sowing-Emergence			Emeregence- CRI			CRI- 50% FLOWERING			50% FLOWERING-MATURITY		
	Max T	MinT	MeanT	MaxT	MinT	MeanT	MaxT	MinT	MeanT	MaxT	MinT	MeanT
Kanchan												
D_1	31.5	16.1	23.8	31.5	16.5	24	29	13.7	21.3	21.4	18.8	20.1
D_2	32	15.9	23.9	29.5	16.7	23.1	28	12.7	20.3	20.4	17.8	19.1
D_3	27.4	16.2	21.8	28	16.5	22.2	30.6	13.2	21.9	21.9	19.0	20.5
HD-2967												
D_1	31.2	18.2	24.7	31.6	15.5	23.5	28.4	12.3	20.3	20.4	17.7	19.0

D_2	32	17.9	24.9	29.3	15.4	22.3	28.4	13	20.7	20.7	18.1	19.4
D_3	27.4	18.2	22.8	28.3	15.5	21.9	31	12.2	21.6	21.6	18.5	20.0
CG-1013												
D_1	31.5	15.7	23.6	31.4	12.9	22.1	28.6	14	21.3	21.3	18.9	20.1
D_2	32	15.7	23.8	29.5	12.6	21.0	28.3	14.8	21.5	21.6	19.3	20.4
D_3	27.6	16.2	21.9	28.2	12.7	20.4	30.5	14	22.2	22.3	19.5	20.9

Rainfall during growth stages

Data regarding rainfall during different phenological stages under different environment and wheat varieties are summarized in table 3. Data presented in table 3 reveals that wheat variety Kanchan sown on 15 November, 2015 experienced 4.4 mm, 9.4 mm, 2 mm and 0.2 mm rainfall during tillering, ear emergence, 50% flowering stages and dough stage and at other stages no rainfall during crop growth period has been onward the total average rainfall of 15 November date of sowing are 16.1 mm during growth period. Wheat variety HD-2967 sown on 15 November to 15 December, 2015-16 experienced 4.4 mm, 9.4 mm, 2 mm, 0.3 mm and 0.6 mm rainfall for CRI, tillering, ear head emergence, dough and maturity stages and total average rainfall are 16.7 mm respectively. The overall total amount of rainfall in all three growing environments on HD-2967 wheat variety is between 11.5 mm to 16.7 mm. Then CG-1013 wheat variety has sown on 15 November to 15 December, 2015-16 experienced 9.4 mm during CRI stage than received 2 mm, 0.3 mm, 0.6 mm and 2.9 mm rainfall in emergence, flowering, dough and maturity stage. Total rainfall for CG-1013 variety received 15.2 mm during different growing environments. Total amount of rainfall covering all crop growth periods of experiment has been observed to be 19.6 mm.

Table 3: Rainfall (mm) during different phenological stages of wheat varieties

DAS	Emergence	CRI	Tiller	Ear emergence	50% Flowring	Milk stages	Dough	Maturity	Average
Kanchan									
D_1	0.0	0.0	4.4	9.4	2.0	0.0	0.3	0	16.1
D_2	0.0	0.0	13.8	0.0	2.0	0.0	0.3	0.6	16.7
D_3	0.0	0.0	4.4	9.4	2.0	0.0	0.3	0.6	16.7
HD-2967									
D_1	0.0	4.4	9.4	2.0	0.0	0.0	0.3	0.6	16.7
D_2	0.0	4.4	1.3	2.0	0.0	0.3	0.0	3.5	11.5
D_3	0.0	4.4	9.4	2.0	0.0	0.3	0.0	0.6	16.7
CG-1013									
D_1	0.0	9.4	0.0	2.0	0.3	0.0	0.6	2.9	15.2
D_2	0.0	9.4	0.0	2.0	0.3	0.6	2.9	0	15.2
D_3	0.0	9.4	0.0	2.0	0.3	0.0	0.6	2.9	15.2

Sunshine hours during growth stages

Data regarding sunshine during different phenological stages under different growing environments has been shown in table 4. Data presented in table reveals that wheat variety Kanchan sown in different growing environments experienced different sunshine hours. The highest sunshine observed at milking stage from D_1 to D_3 for Kanchan was 8.6, 9.0 and 8.7 / hrs and lowest sunshine at has been observed maturity stage 4.3, 4.5 for D_1, D_3 and was lowest for D_2 in tillering stage valuing 3.9 /hrs. Wheat variety HD-2967 sown in different growing environment experienced. The highest sunshine recorded on 50% flowering stage and lowest in tillering stage. Data presented in table reveals that wheat variety CG-1013 sown in different growing environments during crop growth periods. Experienced sunshine very lower data recorded on emergence stage on CG-1013 wheat variety and highest during physiological maturity stage.

Table 4: Bright sunshine hours during different phenology of wheat varieties

DAS	Emergence	CRI	Tiller	Ear emergence	50% Flowring	Milk stages	Dough	Maturity
Kanchan								
D_1	7.3	7.8	5.7	5.0	6.1	8.6	7.4	4.3
D_2	7.2	7.8	3.9	7.8	6.5	9.0	6.0	5.7
D_3	7.0	7.9	4.9	6.2	6.1	8.7	7.2	4.5
HD-2967								
D_1	7.1	4.9	3.4	6.7	8.8	8.0	5.5	5.9
D_2	7.1	4.8	3.4	6.9	8.0	7.5	4.2	7
D_3	7.1	4.9	4.1	6.6	8.9	6.4	5.1	7.6
CG-1013								
D_1	2.5	5.3	7.0	7.6	6.9	3.7	6.5	7.2
D_2	2.5	5.6	7.6	7.5	5.8	4.6	6.8	9.1
D_3	1.3	5.8	7.6	7.4	6.9	4.1	7.4	7.6

Growth parameters

Growth parameters are shown in table no. 5. The mean plant population was significantly higher with variety Kanchan over HD-2967 (National Check) and CG-1013. In timely sown and late sown condition, plant population seems to be optimum while significant less number of plants was observed in D_1 and mortality factor needs to be taken into account.

Plant height seems to be a combination of genetic trait as affected by environmental conditions. HD-2967 attained significant height of 85.1 cm, followed by CG-1013 and

kanchan at par. CG-1013 and kanchan are at par. However there is no effect of growing environment on plant height and different growing environments didn't affect plant height. The highest number of ear heads was observed at maturity with Kanchan (242.6, No. of ear head/m^2) while lowest ear heads was observed in variety CG-1013 (215.2), significant higher than cultivar CG-1013 and at par with HD-2967. On considering the growing environment, it can observed that No. of ear head /m^2 are significantly higher in the crop sown as per recommended package of practice in normal sowing on D_2 as compared to late sown condition D_3. The two treatments of early and late sown are statistically at par. It means on delayed growing environmental condition, this yield attribute is adversely affected.

Table 5: Growth parameters of wheat varieties under different growing environments

Date/ varieties	Plant population/m^2	Plant Height at Maturity	No. of ear head per m^2
D_1-15 Nov.	41.00	83.10	228.20
D_2-30 Nov.	43.80	82.80	237.00
D_3-15 Dec.	43.80	83.10	211.30
S Em (±)	0.71	0.73	8.01
CD (P=0.05)	1.86	1.91	20.81
V_1 Kanchan	45.40	81.70	242.60
V_2 HD 2967	42.60	85.10	218.80
V_3 CG 1013	40.60	82.20	215.20
S Em (±)	1.24	1.27	13.88
CD (P=0.05)	2.15	2.21	24.04
D X V			
S Em (±)	1.24	1.27	13.88
CD (P=0.05)	3.72	3.83	41.63

Acknowledgement
I am greatly indebted to shri. J.L chowdhary and My dear collegues, seniors and all staff of the department of Agrometeorology of IGKV Raipur for the kind assistance during the period of study.

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