Research Article

Yield Comparison of Potential Wheat Varieties by Delay Sowing as Rainfed Crop for Peshawar Climate

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Abstract | Rains are expected to decrease and temperature has to rise for wheat growth in Pakistan. Wheat crop is planted on more than 52% area as rainfed crop in the providence Khyber Pakhtunkhuwa (KP). The study, therefore, aims to plant wheat in season from early to late i.e. November 15 to December 25 with about 10 days intervals. Field experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar in winter season 2015-16. Experiment was in a randomized complete block design, in split plots having three replications. Sowing dates were assigned to main plots and wheat varieties (i.e. Shahkar-2013, Atta-Habib-2010, Pakhtunkhwa-2015, Hashim, Dharabi, Chakwal-50, Pakistan-2013 and Ghanemat-2015) to sub plots. Results revealed that sowing dates and varieties significantly affected yield and yield related traits. Sowing made on November 25 showed higher yield than the expected early sown on November 15 or late sown thereafter on December 5 in season in the region. Overall delay in sowing date i.e. from December 5 onwards resulted in sever losses in biomass and grain yield (GY). On averages of varieties, a decrease in biological- and grain yield was estimated 261 and 89 kg ha^{-1}, reapectively, per day in wheat in season for Peshawar when sowing was postponed from December 5. Early planting delayed days to anthesis and maturity, which otherwise extended grain development phase of the crop. Among varieties, Ghanemat-2015 showed better grain yield for a relatively longer duration i.e. December 5-15 over the others varieties. Atta-Habib also performed relatively better for sowing made on November 25 and Chakwal-50 on November 15. Overall GY reduced when wheat sowing postpones from December 5 in the season. Grains protein was observed high for sowing made on November 15-25 for wheat varieties Dharabi, Shahkar-2013, Pakhtunkhuwa-2015 and Ghanemat-2015 as un-irrigated crop for the area. The study suggests that none of the existing wheat variety has potential to sustain grain yield of wheat if planted on December 5 or thereafter. However, Ghanemat-2015 is relatively better option over the other varieties for Peshawar.

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Introduction

Wheat (*Triticum aestivum* L.) is a dominant crop with grains for staple food consumption and straw for fodder in the world and Pakistan. It is important food component of living being with richest source of protein and energy (Saleem et al., 2007). On the basis of consumption, it ranked first in Pakistan. However, shortage of water is expected at the time of its cultivation in Pakistan due to climate changes (Hanif, 2014). In the province of Khyber Pakhtunkhwa (KP), wheat is cultivated on more

than 52% cropped area as barani crop (rainfed) and its average yield is very low due to unavailability of the appropriate wheat variety for the area's climate and its appropriate time of sowing subject to onset of winter (October-December) rains (Mukhtarullah et al., 2016). Improved cultural practices focusing on conservation of soil moisture from the previous crops and/or subject to rains can ensure timely plantation of the crop. This would sustain the further growth and development of wheat with spring and monsoon rains. Rain-fed lands could be left fallow during monsoon to absorb the maximum moisture in soils for a good wheat crop production in D.I. Khan region. Appropriate variety selection for the rainfed/unirrigated region is major issue in Pakistan and in KP particularly (Naz and Akmal, 2016). In deficient moisture conditions, drought tolerant or resistant varieties can survive better (Upadhyay et al., 2007). Planting date is one of the components for identification of an appropriate wheat variety fits well for growth in the climate subject to its cultivation with onset of winter rain and timings (Khan et al., 2007).

Research proved that a subsequent delay in a day from optimum sowing time has decreased 1% grain yield in general. Delay in sowing can also increase risk of yield loss or crop failure by diseases attack etc. (Gul et al., 2012). Planting time of crops is not only important for environment but also for the magnitude of insects, pests and diseases attack on selection of a variety to escape its critical stage of growth. In the recent past in Pakistan, optimum wheat sowing time was late October that has been gradually shifted to early November due to changes in the climate (Akmal *et al.*, 2014). As rainfall has been delayed and temperature has been raised the wheat crop sowing time has postponed from late October to mid November and expected to move onwards i.e. in early December in the season. Rust attack has also been increased due to more humid and relatively wet spring season. Attack of aphid on wheat spike is also increasing both on irrigated and dry lands' crop (Hanif and Ali, 2014; Mukhtarullah et al., 2016). Temperature and moisture are the two important factors of the climate scenarios, which govern growth of plants in rain-fed areas. However, temperatures determine length of a crop growth season in the area (Haq et al., 2002). Sowing time of the crop depends on moisture availability in soil and soil temperature to initiate seed germination in season. Optimum moisture at sowing time guarantees crop establishment with better stand. Therefore, the study aims to evaluate high yielding varieties appropriate for rainfed regions by planting on wet land starting from November 15 with 10 days interval to very late sowing in season. Sowing was made for about two months from optimum to late in season to identify appropriate variety fits well for high production on rainfed land as un-irrigated crop.

Materials and Methods

Site and location

Selected high yielding good wheat varieties were planted from November 15, 2015 with 10 days interval to compare yield performance of the varieties to be recommended for sowing in rainfed i.e. un-irrigated conditions. The experiment was conducted at Agronomy Research Farm, the University of Agriculture Peshawar, Pakistan. The experimental site is located 34.01^0 N 71.35^0 E at an altitude of 350 m above the sea level. Soil of the experimental site was silty loam with a very low total N content estimated around 0.032 % at the crop sowing, 0.045 % at the crop anthesis stage and around 0.041 % at the crop harvest. Mineral N content (NH_4) was measured 48 mg kg^{-1} at seedbed preparation, 65 mg kg^{-1} at anthesis and 57 mg kg^{-1} at harvesting of the crop. Nitrate-N (NO_3) was 51 mg kg^{-1} at sowing, 70 mg kg^{-1} at anthesis and 62 mg kg^{-1} at the crop harvest. Mean daily temperature of the crop growth season (from Nov. 15, 2015 to May 15, 2016) was 24.4±6.68 ^{O}C for the maximum and 10.40±6.25 ^{O}C for the minimum readings. Weather data of the experimental site for crop growth season is shown in Figure 1.

Design and treatment layout

Experiment was conducted in a randomized complete block design, split plot arrangement in three replications. The planting intervals (i.e. November 15, 25, December 05, 15 and 25) were assigned to main plots and varieties (i.e. Shahkar-2013, Atta-Habib-2010, Pakhtunkhwa-2015, Hashim, Dharabi, Chakwal-50, Pakistan-2013 and Ghanemat-2015) to subplots. Each experimental unit was 4 x 1.5 m accommodating 6 wheat rows at equally spaced 25 cm distances. Field was initially irrigated with floodwater (estimated 60 mm rainfall) for 1st sowing. On appropriate soil moisture content, seedbed was prepared with tractor for the 1st sowing date while the rest of the filed was covered with two layers of plastic sheet to conserve moisture content and avoid extra seasonal rainfall. Field capacity under the sheets was conserved optimum for 2nd and 3rd sowing dates by decreasing seas-

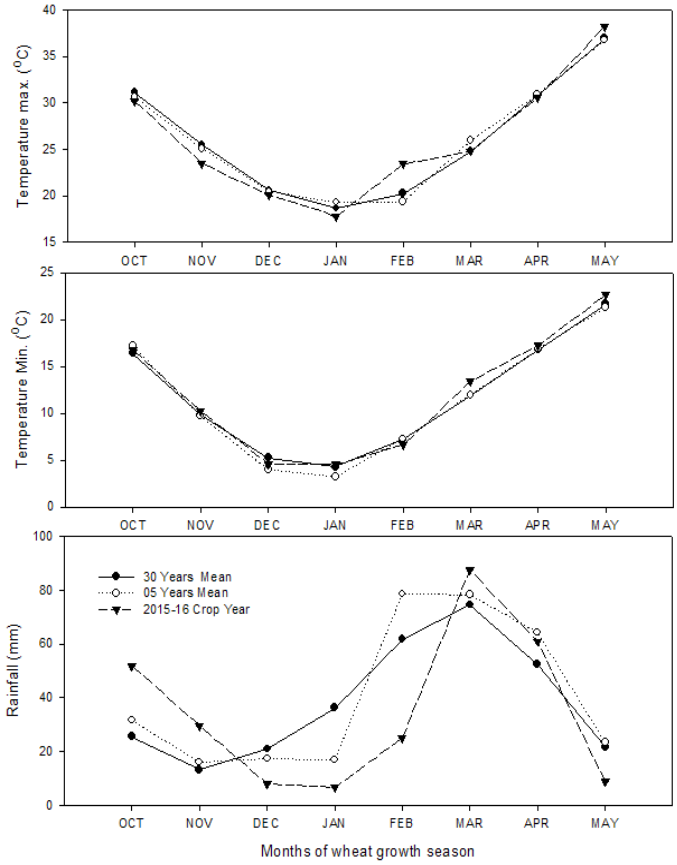

Figure 1: *Changes in climate scenarios (Temperature & Rainfall0 observed for wheat crop growth period in Peshawar (Source Pak. Met. Department).*

onal temperature and occurrence of rains. However, the remaining main plots were irrigated well advanced to achieve the desired moisture content for the 4th and 5th sowing date. For the sowing interval experiment, field layout was made 4m wide with a 0.5m bifurcation with temporary ridge as main plot to be designated as sowing date plots. These plots were randomly assigned the sowing intervals and labeled. Seedbed was prepared for each sowing date uniformly. Nutrients were applied before seedbed preparation as recommended for rainfed wheat i.e. one bag each Urea and Di-ammonium-phosphate (DAP) per acre at sowing. Wheat varieties were planted in rows in main plots and replications. Nitrogen was applied additionally one bag per acre at stem elongation stage on February 11, 2016 due to higher rainfall in the season in spring. Planting was done with 130 kg ha^{-1} seeding rates for each variety. Other agronomic practices e.g. weeding etc. were uniform. Crop was harvested on May 04 for 1st and 2nd sowing dates, May 9 for 3rd sowing and May 15, 2016 for the rest sowing dates i.e. 4th and 5th.

Measurements and Observations

Data regarding days to anthesis were counted from selected portion of the experimental unit when 80% anthers formation observed in it. Total tiller was recorded manually by counting tillers in a meter long row at three randomly selected spots when crop was ready to harvest. Mean of three samples were divided by sampled row length, number of rows and row spacing. Productive tillers were counted having spikes in that sample. Plant height (cm) was recorded randomly by measuring height of 10 tillers in an experimental unit. Days to maturity were recorded when plants were physiologically matured. Grains $spike^{-1}$ was recorded on 10 selected spikes by threshing and manually counting grains. Thousand grains weight (g) was recorded on counting thousand grains with a seed counter. Biological and grain yield (kg ha^{-1}) were recorded by harvesting four central rows, bundled and sundried in field and weighed before and after threshing each bundle separately in a mini lab thresher at the farmhouse. Grain protein content (GPC %) was observed on Near Infrared Reflectance Spectroscopy (NIRS) at Nuclear Institute for Food and Agriculture (NIFA), Peshawar. GPC were derived by non-destructive procedure filling whole grains in sampling cups designed for the NIRS (Model Antaris II, Thermo Scientific, USA). The machine was first calibrated for wheat grains with pre-runs samples equations. Wheat samples were run on NIRS at energy absorbed band 1100-2500 nm. Precision of NIRs methods depends on reference equations ($r^2 = 0.99$).

Statistical Analysis

The data were analyzed statistically using analysis of variance techniques suitable for randomized complete block deign, split plot arrangement. Significant differences among the various treatment means were determined using least significant difference (LSD) test ($p \leq 0.05$) for main, sub treatments and their interaction (Steel and Torrie, 1980).

Results and Discussion

Late sowing would have definitely delayed emergence, however, it was not markedly among varieties (data not shown). This duration varied from 7 to 14 days by delay in sowing made from early to late in the season, which was due to decrease in the daily mean temperature as shown in Figure 1 (Mumtaz et al., 2015; Aslani and Mehrvar, 2012). The most interesting parameter of the varieties and sowing date was days to anthesis, which terminated the vegetative growth of the crop (Aslani and Mehrvar, 2012;

Rehman et al., 2009). Days to anthesis (DTA) were significantly ($p<0.05$) affected by sowing dates and varieties (Table 1). On averaged across varieties, the November 15 sowing took the maximum days to anthesis, followed by November 25, December 05 and December 15 with the minimum days to anthesis for December 25. All five sowing dates were different ($p<0.05$) from each other. On averaged across sowing dates, wheat varieties also differed ($p<0.05$) from each other with maximum days taken by Chakwal-50, followed by the Pakhtunkhwa-2015, Ghanemat-2015, Shahkar-2013, and Atta-Habib. Wheat varieties Hashim, Pakistan-2013 and Dharabi were same for days to anthesis. Yield performance is product of genotype and environment. Delay in sowing has limited the vegetative growth duration by extending a bit the emergence duration. Wheat crop avails winter dormancy opportunity under Peshawar's climate due to close to freezing temperature in the months of December and January. However, crop initiate flowering under favorable climate of the season in March. In the Peshawar climate, post anthesis temperature rose sharply and days to anthesis approached early for the late sown crop that reduced plant life cycle with adverse effect on grain development phase of the wheat crop. Interaction of treatments for days to anthesis was non-significant.

Tillers density (TD) remained same ($p<0.05$) when sowing was made between November 15 and December 05, thereafter tiller density decreased ($p<0.05$) for every subsequent sowing made on December 15 and December 25. Late planting has reduced tillers density due to winter injury to buds initiate tillers and/or unavailability of breaking dormancy with light of the season (Gul et al., 2012). While averaged across sowing dates, highest TD reported for Ghanemat-2015, followed by Pakhtunkhwa-2015, Shahkar-2013, Pakistan-2013, Dharabi and Chakwal-50 varieties with lowest for Atta-Habib. Interaction for TD data was non-significant ($p<0.05$). Productive tillers (PT), having spikes, were the maximum for December 05 sowing, followed by November 25 and 15. Differences do exist between varieties for tiller density due to their performance efficiency in the existing climate (Gul et al., 2012; Shah et al., 2006). Averaged across sowing dates, the maximum productive tiller (PT) was observed in Ghanemat-2015 variety, followed by Pakhtunkhwa-2015, Shahkar-2013, Hashim and Pakistan-2013. The minimum PT was observed in Atta-Habib that did not differ with Chakwal-50 and Dharabi. Plant height (PH) did not differ ($p<0.05$) for sowing dates but differed for varieties ($p<0.05$). Tallest plant was observed for Dharabi, followed by Pakistan-2013, Hashim and Ghanemat-2015. Relatively medium height was observed for Shahkar-2013, followed by Atta-Habib, Pakhtunkhwa-2015 and Ckakwal-50. Difference in plant height is subject to variety performance in soil and climate (Nizamuddin et al., 2014). Varieties planted late in the season have faced the unpleasant weather and hence decreased height from the normal due to adverse climate of the season. Dharabi showed taller plants that were statistically significant ($p<0.05$) to all other varieties, e.g. Pakistan-2013, Hashim, Ghanemat-2015, Shahkar-2013, Atta-Habib-2010, Pakhtunkhwa-2015 and Chakwal-50 were statistically similar in height. Interaction was non-significant for plant height data. Variation in spike density from total tiller density is a natural phenomenon and has already been reported in the previous literature for same soil and climate except varieties (Upadhyay et al., 2015). Days to maturity (DTM) were significant ($p<0.05$) for sowing dates only. November 15 sowing took maximum days to maturity followed by November 25, December 05, December 15 and December 25. All five planting intervals were significantly different from each other for DTM. Days taken to mature a variety are subject to its life cycle completed from onset of anthesis that varies with changing environment subject to its sowing time (Mukhtaruualah et al., 2016) and hence the grain yield affected accordingly.

Data regarding grains spike^{-1} (GS) were non-significant ($p<0.05$) for sowing dates, however, found significant for varieties (Table 2). By averaged across sowing dates, the maximum GS was recorded for Atta-Habib variety of wheat, which was statistically at par with Dharabi, Ghanemat-2015, Hashim and Pakhtunkhwa-2015. The minimum GS was observed for variety Shahkar-2013. Interactions for GS were significant ($p<0.05$). Mean readings showed different trends for varieties when sowing was delayed from November 15 to December 25 (Figure 2a). Most of the varieties remained stable for GS when sowing was delayed (November 15-25). However, Atta-Habib showed an increase in GS with delay in sowing. All varieties were stable in GS date when planting was made on November 15, 25 and December 05 in season. Thereafter, variety Hashim showed better GS. Variety Atta-Habib also showed higher GS on last sowing made in December 25. However, GS decrease

Table 1: *Crop coefficient i.e. days to anthesis (DTA), tillers density (TD), productive tillers (PT), plant height (PH) and days to maturity (DTM) of wheat varieties planted on different dates as un-irrigated crop.*

Sowing dates (SD)	DTA	TD (m^{-2})	PT (m^{-2})	PH (cm)	DTM
November 15	125.4 a	226 a	213 a	86 a	162.3 a
November 25	121.5 b	228 a	214 a	88 a	156.5 b
December 05	116.7 c	231 a	218 a	86 a	148.0 c
December 15	113.8 d	210 b	195 b	87 a	142.9 d
December 25	106.2 e	185 c	171 c	83 a	136.9 e
LSD (p<0.05)	0.93	6.59	8.28	ns	0.77
Varieties (V)					
Shahkar-2013	116.7 abc	216 b	201 bc	84 cd	149.7 a
Atta-habib-2010	116.7 bcd	211 c	197 c	83 d	149.5 a
Pakhtunkhuwa-2015	117.4 ab	218 ab	206 ab	82 de	149.2 a
Hashim	116.4 cd	215 bc	201 bc	88 bc	149.5 a
Dharabi	115.8 d	215 bc	200 c	96 a	148.9 a
Chakwal-50	117.6 a	215 bc	200 c	78 e	149.3 a
Pakistan-2013	116.2 cd	215 bc	201 bc	90 b	149.2 a
Ghaneemat-2015	116.9 abc	223 a	210 a	87 bc	149.1 a
LSD (p<0.05)	0.9	5.22	4.56	4.12	ns
SD x V	Ns	ns	ns	ns	ns

Table 2: *Grains spike^{-1} (GS), 1000-grains weight (TGW), biological yield (BY), grain yield (GY) and grain protein content (GPC) of wheat varieties planted on different dates as un-irrigated crop.*

Sowing dates (SD)	GS	TGW (g)	BY (kg/ha)	GY (kg/ha)	GPC (%)
November 15	37 a	41.01 a	8662 b	3244 b	15.1 a
November 25	38 a	41.03 a	9313 a	3535 a	15.1 a
December 05	42 a	41.05 a	7969 c	3144 c	14.9 b
December 15	37 a	41.13 a	5968 d	2331 d	14.8 b
December 25	43 a	41.10 a	3881 e	1523 e	15.0 a
LSD (p<0.05)	ns	ns	140.44	76.13	0.09
Varieties (V)					
Shahkar-2013	31 d	38.5 g	7191 d	2864 c	15.1 b
Atta-habib-2010	45 a	40.5 e	6506 f	2528.g	14.9 c
Pakhtunkhuwa-2015	39 bc	38.8 f	6946 e	2520 g	15.1 b
Hashim	40 bc	40.7 d	6954 e	2647 f	14.9 c
Dharabi	42 ab	43.3 b	7583 b	2944 b	15.4 a
Chakwal-50	38 c	40.7 d	7046 e	2783 d	15.3 a
Pakistan-2013	38 c	43.5 a	7309 c	2724 e	14.5 d
Ghaneemat-2015	41 bc	42.5 c	7734 a	3033 a	14.9 c
LSD (p<0.05)	3.34	0.17	109.55	54.35	0.08
SD x V	*	**	***	***	***

Mean followed by a common letter within a category are non-significant to each other using LSD (p<0.05) test.

-d in general for sowing made in December 05 or thereafter in season. Thousand grain weight (TGW) were non-significant (p<0.05) for the sowing dates however, differed (p<0.05) for varieties. Averaged across sowing dates, the highest TGW was recorded for variety Pakistan-2013, followed by Dharabi, Ghaneemat-2015, Chakwal-50, Hashim, Atta-Habib and Pakhtunkhwa-2015. The minimum TGW was noted for variety Shahkar-2013. Interaction was significant (p<0.05) for TGW. The TGW was found almost sta

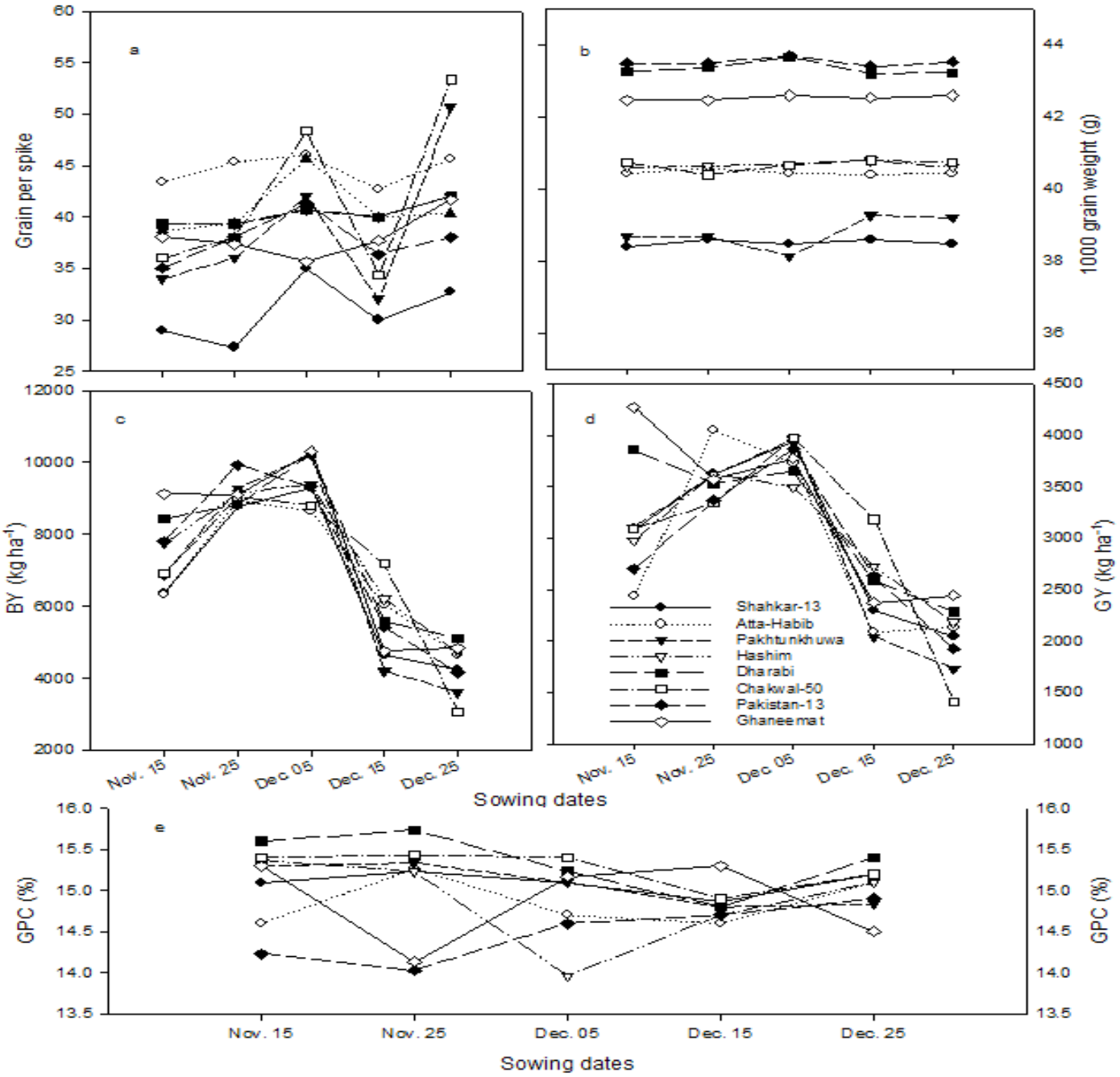

Figure 2: *Interactive response of wheat varieties and sowing date effect for different traits (i.e. a. grains per spike, b. 1000 grains weight, c. biological yield, d. grain yield and e. grain protein content) of wheat.*

ble for sowing dates for a variety . However, TGW was observed relatively higher for varieties Hashim, Dharabi and Pakistan-2013 (Figure 2b). Thereafter, TGW was observed better for variety Ghanemat-2015. TGW for rest of the varieties were lower.

Biological yield (BY) was the maximum for November 25, followed by November 15, December 05 and December 15 with minimum weight for December 25 sowing in season . All sowing dates were significantly different from each other. While averaged across sowing dates, the maximum BY was recorded for Ghanemat-2015, followed by variety Dharabi, Pakistan-2013, Shahkar-2013 while Chakwal-50, Hashim and Pakhtunkhwa-2015 with statistically the same ($p<0.05$) BY. Lowest BY was observed for Atta-Habib. Trend lines for delay sowing dates of wheat showed an increase in BY for delay sowing in season from November 15 to 25 and subsequently for December 5 for almost all varieties but thereafter BY decreases for all varieties for further delay in sowing made in the season (Figure 2c). Ghanemat-2015 and Dharabi showed better BY than rest of the varieties at late sowing dates. A decrease in BY was common for all varieties for very late sowing dates in mid-December onwards. Irrespective of varieties, loss in BY (kg

ha^{-1}) with delay sowing was observed from December 15. Sowing made for wheat in November in Peshawar and other areas having similar climate is the optimum time under recent climate change. Sowing delay in December decreased BY due to decrease in growth by the low temperature that has delayed emergence and slowed down the vegetative increments in the season with lower mean temperature (Mukhtarullha et al., 2016). The regression made for sowing dates starting from November 15 as day 1st and thereafter with adding the respective intervals (Figure 3) has shown about 261 kg loss per day in biomass of wheat (r^2 = 0.91). Grain yield (GY) was the highest for November 25 sowing date, followed by early sowing made in season i.e. November 15, and/or thereafter in December 05. GY decreased drastically for December 15 and 25 in season. Averaged across sowing dates, the maximum GY was reported for variety Ghanemat-2015, followed by Dharabi, Shahkar-2013, Chakwal-50, Pakistan-2013 and Hashim and minimum for Pakhtunkhwa-2015 and Atta-Habib. Interactive effects of sowing date and varieties were significant for GY (Figure 2d). The maximum GY was associated to early sowing for Ghanemat-2015, Hashim and Dharabi, followed by narrow differences with other varieties for the November 25 and December 5 sowing dates. Delay in sowing for mid December has reduced GY with accepted values Hashim, Dharabi and Ghanemat-2015 when crop was sown very late in season on December 15 and/or December 25. This showed that both varieties are relatively better to perform in the area if planting is delayed in season due to any of the eventuality of water shortage or land availability for wheat sowing in the region. One possible reason could be that their dormancy period was either less affected by low temperature or they had flowered earlier in season than rest of the varieties (Naz and Akmal, 2016). A reduction in GY was common for all varieties but with different rates. Irrespective of varieties, GY decreased for a delay in sowing made on November 25 onwards in the season and even reported for an early sowing made on November 15 due to recent climate changes i.e. higher temperature and drought. This shows the optimum sowing time for wheat in the area has been shifted further late in November in season. Thereafter, a delay in sowing has significant effects on GY losses due to low temperature, which limits vegetative growth duration (Figure 3). Regression for sowing date and grain yield (Excluding 1st, 2nd and 3rd sowings) showed losses in grains yield and are expected by 89 kg ha^{-1} per day (r^2 = 0.93). Difference

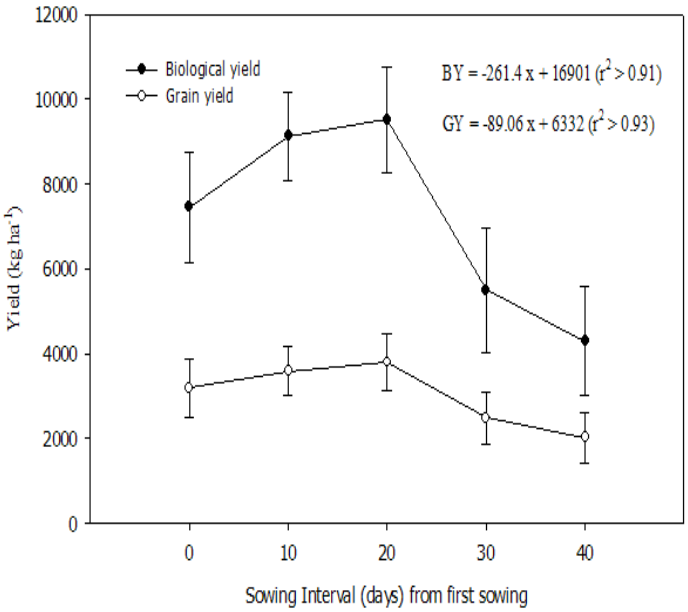

Figure 3: *Gain and loss in average yield (biomass and grains) of wheat in season due to delay in sowing date from November 15 onwards.*

in yield was mainly due to differences in yield traits that were sensitive to sowing dates, which had adversely affected GY of wheat. It might be due to variety character being different in morphology and flag leaf area and green-duration that sustained source sink relationship. Sowing made late in December 5 onwards i.e. December 15 and 25 showed reduction in BY and GY due to decreases in plant density and stature i.e. leaf area, leaf number, size and duration etc., which ultimately contributed to biomass and yield. A significant effect on yield per unit area for varieties is common in wheat (Mumtaz et al., 2015). Varieties also differed in performance and was the objective of this study to identify good variety that is relatively better to plan on a late sowing date if rain occurs late in season or field is not free for sowing. Grain protein content (GPC) revealed higher value (%) for sowing made on November 15 and 25, but decreased thereafter for sowing made on December 05 and 15. While averaged across sowing dates, the higher GPC (%) was observed for Dharabi followed by Chakwal-50, Shahkar-2013 and Pakhtunkhwa-2015, Atta-Habib-2010, Hashim and Ghanemat-2015 with lowest for Pakistan-2013. Interaction between sowing dates and varieties showed higher GPC for Dharabi when planted on November 25 and 15, respectively and lower for Pakistan-2013 and Hashim planted on November 25 and December 05, respectively (Figure 2e). The GPC of varieties exhibited disorder for different sowing dates i.e. November 15 onwards. Early planting of a crop flowers in time, which enable plant

with sufficient time for grains development. Crop planted late in season have squeezed its life cycle by limiting the grain development duration. For wheat crop temperature after anthesis increased faster and hence mature grains in shorter duration (Abdullah et al., 2007; Shazad et al., 2007). Differences within variety do exist while their genetic make is diversified from each other for the carbohydrates and other assimilates e.g. GPC.

Conclusion

From findings of the research study, most appropriate sowing date for wheat in the season has a bit shifted from early to late November i.e. November 25 to December 5 for Peshawar valley condition. It is due to recent climatic changes observed in the valley (Figure 1). However, a delay of wheat sowing due to any of the eventuality i.e. drought stress, high soil temperature, or availability of land by harvesting a previous crop, results in yield losses of about 89 kg grains and 261 kg biomass of wheat crop for any of the best variety on a hectare basis. Nonetheless, Ghanemat-2015 can be a relatively good option to plant late in season with relatively less yield losses per unit area if sowing has been postponed in December 05 in the season.

Authors Contribution

Kamran A. Awan did the research work and prepared the manuscript. Jawad Ali designed the study and supported overall and Mohammad Akmal supervised the research.

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