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Studying Relationships among Yield and Yield Traits in Mexican Wheat Genotypes

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***Abstract: :** A field study was carried out during 2018-19 to assess relationships among yield and yield traits in 15 Mexican wheat genotypes; and the breeding material comprised of Mexican Line 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35. In addition to recording the growth and yield performance, ANOVA, correlation coefficient and regression analysis were also performed to examine the contribution of different traits in grain yield variability. RCB design with three replicates was used for the experiment. The mean squares from the ANOVA have suggested significant difference in their growth and yield traits ($P<0.05$) from each other. The significance of differences in the values of studied traits of Mexican wheat lines might be the genetic influence corresponding to genetic makeup of parental material of these wheat lines. The Mexican lines used as breeding material produced significantly different yield performance ($P<0.05$). Mexican Line-25 produced maximum yield performance, followed by Mexican Line-28, Mexican line-32, Mexican line-29 and lowest yield plant^{-1} was recorded in Mexican line-23. The Mexican Line-25 showed its superiority in plant height, tillering capacity, seeds spike^{-1} as well as in grain yield plant^{-1}. Mexican Line-28 and Mexican Line-32 also showed most promising results for grain yield plant^{-1}. There was significant and positive ($P<0.05$) correlation for tillering capacity plant^{-1} vs grains number spike^{-1} (r=0.3241*), tillers number plant^{-1} vs yield plant^{-1} (r= 0.6223**), spike length vs seed index (r= 0.3692**), spike length vs grains spike^{-1} (r=0.3291*) and spikelets spike^{-1} vs grains spike^{-1} (r= 0.3642**). However, there was negative and significant ($P<0.05$) association was recorded for plant height vs spike length (r= -0.3951**), plant height vs seed index (r= -0.6428**) and tillers plant^{-1} vs spike length (r= -0.3585**). The coefficient of determination (r^2) suggested 2.18% decrease in grain yield with increasing plant height; and 37.30 percent increase in grain yield was described by increase in tillers plant^{-1}; while 1.73% variation in grain yield was linked with spike length variation. Similarly, 3.50% variation in grain yield was guided by the variation in spikelets spike^{-1} and 0.63 percent variation in yield was guided by change in grains spike^{-1}; while 2.97% change in grain yield was associated with the change in seed index.*

Keywords: Studying Relationships Among Yield And Yield Traits In Mexican Wheat

INTRODUCTION:

Hexaploid wheat (*Triticum aestivum*), cultivated worldwide (Moon, 2008) is the principal source of human diet with prominent position among cereals, particularly in the Asia and more specifically in the south Asian region supplying 68 percent of the calories and protein in the diet (Shewry, 2009). Wheat flour is used for leavened, flat and steamed breads as well as most of the baked products (Cauvain *et al.*, 2003). The daily diet of people in Pakistan is mainly based on wheat (Farzi and Bigloo, 2010). Importance of wheat in Pakistan can be noted from the fact that agricultural policies are formulated focusing this crop; and more than 60% diet of humans in the country is based on wheat with 125 kg per capita consumption of 125 kg (Khan and Habib, 2003).

Pakistan is known to be the most important country where wheat is cultivated extensively in its all ecological conditions and included in world top ten wheat producing countries (Khan *et al*., 2002), but the average yields are much lower than other major wheat growing countries including China, USA, India etc. (Arain *et al*., 2005). Being the leading food grain of Pakistan, wheat contributes 10.0% to agriculture value added and 2.1% to GDP. Pakistan Economic Survey 2014-15 (GOP, 2015) reveals that wheat is cultivated on an area of 9,180,000 hectares in 2014-15; while during last year (2018-19), the crop was cultivated on 9,199,000 hectares indicating a minor decrease in area. Similarly, during 2014-15, the wheat grain production was 25.478 million tons showing 1.9 percent decrease compared to 25.979 million tons produced during the year 2018-19 (GoP, 2015).

Grain yield obtained in the country is lower than the existing potential of varieties under cultivation. The low yield is attributable to many factors that include various agronomic factors (Alam *et al.,* 2003) such as improper inputs application

(Korres and Froud, 2002; Yongqing, 2005). Moreover, the low yield is also attributable to environmental factors as well as varietal potentiality. However, the variety and genetic variability mainly cause variation in wheat yield (Alam *et al.*, 2003).

The yield of wheat varies under the interactive influence of various environmental factors, because the grain is contributed by numerous factors that have direct or indirect effect on grain yield. The grain yield can be improved by evolution and development of high yielding wheat lines with better adaptability across environments as well as possess resistance to multiple stresses. The selection of lines for yield improvement is only successful if the breeding material being used possesses enough genetic variability (Ali *et al*. 2008). Among important breeding aspects, genotypic correlation and phenotypic correlation are considered as most important for assessing the association extent in relation to yield contributing traits with grain yield (Goksoy *et al*. 2003; Ali *et al*. 2009).

The wheat breeding, scientists emphasize on improving yield potential in wheat by evolving new crop varieties possessing genetic potential to produce desired grain yields. The understanding association among character influencing yield is of prime importance for development of a successful plant-breeding program (Worley *et al.,* 1976). The knowledge in regards to character association among the growth and yield related parameters and grain quality traits is of great importance to identify yield contributing character (Baloch *et al.,* 1992).

Correlation studies are an important phase of plant breeding which started in the last decade of 19th century and the beginning of 20th century. In order to simplify breeding work and easy handling of material, such investigations have continued to be carried out on various types of crop plant (Aycecik and Yildirim, 2006). Correlations studies are attempted to detect one or few morphological characters which can easily be evaluated and provide selection basis for other desirable plant traits. Vailvon (1951) pleaded pleiotrophic gene effects being major cause of genetic correlations, as a number of characters are be conditioned the effect of single gene. Correlation is the instantaneous variation in two variables (Goksoy *et al*. 2003). The change in one result into a proportionate variation in the other and it may be positive or negative. Positive correlation indicates that an increase in one character will bring simultaneous increase in the other associated character; whereas, negative correlation suggests that an increase in one character causes decrease in the other associated character. So the positive correlation between two desirable characters and negative correlation between a desirable and undesirable character is important (Shahid *et al*. 2002; Ali *et al*. 2009).

The genotypic improvement has on the basis of phenotypic correlation amongst grain yield contributing variables with yield have comprehensively been examined in the world as mentioned buy Aycecik and Yildirim (2006); while Akram *et al*. (2008) identified positive and significant correlation of 1000-grain weight with grain yield and Kashif *et al.*, (2007) yield traits in wheat such as tillering capacity had remarkable contribution to grain yield. Similarly, spikes per metre square, number of grains per spike and seed index value was contributed significantly to grain yield. Moreover, there was significant and positive correlation between yield plant^{-1} and productive tillers, height of the plant, seed index and length of spikes at genotypic and phenotypic levels as achieved by Aycecik and Yildirim (2006). Some negative association of grain yield with height of the plant was observed; and spikelets per spike were also negatively correlated with seed index as obtained by Shahid *et al*. (2002). There was negative correlation between spikelets spike and seed index value. Lad *et al*. (2003) observed that there was positive and significant correlation between yield and tillering capacity as well as spikelets spike^{-1} both at genotypic and phenotypic levels. Some other breeders such as Kashif *et al.,* (2007) concluded that height of plant, length of spike, number of spikelets spike^{-1} and seed index value exhibited positive and significant correlation with yield plant^{-1} at genotypic level (Aycicek and Yildirim, 2006).

Since the correlation coefficients generally show relationships among independent variables and the degree of linear relations among the variables, they could not sufficiently describe the relationship when a clear cause-result relationship was found between the variables (Dokuyucu *et al*. 2002; Turk and Celik, 2006; Kara and Akman, 2007). The understanding interrelationship of factors influencing yield is a pre-requisite for designing an effective plant-breeding program (Worley *et al.,* 1976). The information about the simple correlation of agronomic, morphological and quality characters with yield is helpful in identification of the yield component (Baloch *et al.*, 1992). The present experiment was mainly aimed at studying relationships among yield and yield traits in Mexican wheat genotypes.

REVIEW OF LITERATURE:

Singh *et al*. (2003) conducted studies on correlation among morphoyield traits in 50 genotypes of bread wheat and revealed positive and significant association between plant effective tillers number, total per plant biomass (biological yield) and grain percentage (harvest index%) with per plant grain yield.

Humaira *et al*. (2004) conducted experiment to determine the genotypic variability and association of grain yield trait with its contributing traits in wheat and triticale. The material comprised of 28 advanced triticale breeding lines and wheat cultivars. Data were recorded on spikes number per plant 1000 weight of grains (seed index value), grains number per spike and yield. The genotypes were significant for spikes plant^{-1}, 1000 weight of grains (seed index value) and grains number per spike. However, the genotypes did not significantly differ for yield. The genotypic and phenotypic correlations of 1000 grains weight (seed index value) with grains number per spike, spike number per plant^{-1} and total grain yield were non-significant. The phenotypic correlation of grains number in a spike or in a plant with grain yield was significantly positive. The genotypic correlation of spikes number plant with grain yield was significantly positive.

Kashif and Khaliq (2004) studied interrelationships among morphoyield traits in wheat and reported that height of the plant, length of spike, spikelets number per spike, grains number per spike and seed index value (1000-grains weight) correlated significant and positive manner with yield at the genetic level, and at the phenotypic level these traits were significantly ($P<0.05$) associated with yield.

Kumar *et al.* (2004) carried out studies on interrelationship of yield and its components in four wheat cultivars (PBW 343, WH 711, Raj 3765 and Sonak) sown under varying dates of sowing (5 and 20 November, 5 and 20 December, and 5 January) which showed that yield had significantly positive association with the number of days taken to maturity, test weight and spikes number per meter row length. The correlation between seed yield and its components was significant for all the characters in both the years of study.

Josm (2005) estimated correlation to evaluate the importance of different agromorpholgical traits in common and Tartary buckwheat. The direction and magnitude of the association between the traits were found to be different in these two species. Flowering days were negatively correlated (-0.355*) with maturity days in Tartary but had no correlation (0.083) in common buckwheat. Maturity days had a significant positive correlation with plant height (0.394*) and grain yield (0.340*) in Tartary buckwheat. A negative association between maturity days and 1000-grains weight (seed index value) was significantly different in both species.

Safeer-ul-Hassan *et al.* (2005) recorded and analysed data on days to heading, days to maturity, plant height, spike length, spikelets number per spike, grains number per spike, weight of grains per spike, 1000-grains weight (seed index value) and yield per plot for wheat genotypes. The genotypes were highly significant for all the traits except for yield per plot where a significant difference was observed among the genotypes. The calculated correlation coefficients indicated that spikelets number per spike, days to maturity and plant height were significantly positive correlated with grain yield per plot, while a non significant correlation was observed between grain yield per plot and number of grains per plot, days to heading, weight of grains per spike, 1000-grains weight (seed index value) and spike length. Genotype V4 and V15 performed better for most of the traits and can be considered for release as varieties after further evaluation.

Akhtar and Chowdhary (2006) studied interrelationship in phenotypic and genetic sense for nine yield components in two bread wheat crosses V-95199 x PARI-73 and Chakwal-86 x V-8060 and their reciprocals. The genetic variances were found to be greater than phenotypic variances for all the plant parameters in both the crosses and their reciprocals. The inter-relationship among all the traits studied in both crosses revealed that grain yield could efficiently be increased by obtaining maximum expression of height of the plant, tillering capacity per plant, length of spikes, 1000-grains weight (seed index value) and biomass per plant.

Aycicek and Yildirim (2006) conducted studies across two locations and over two years was calculated between grain yield and yield components of 20 bread wheat genotypes. Significantly positive correlation was found between yield and plant density, height of the plant, grain number per spike, weight of grains per spike and 1000 kernels weight. Grain yield was negatively and significantly correlated with time to heading. Positive direct effect of height of the plant and per spike weight of grains and negative direct effect of time to heading associated with significant correlation with grain yield suggested that these yield components may be good selection criteria to improve yield of wheat genotypes.

Biju and Malik (2006) studied correlation and their results revealed that the wheat genotypes showed variation in height of the plant, tillering capacity per plant, ear length, number of grains per ear, 100-weight of grains, seed weight and harvest index. Grain yield per plant was moderately correlated with ear length, tillering capacity per plant and number of grains per ear. One-hundred seed weight was negatively correlated with and number of grains per ear.

Mehmet and Yildirim (2006) calculated correlation coefficients and path analysis between grain yield and yield components of 20 bread wheat genotypes. Significantly positive correlation was found between yield and plant density, height of the plant, grain number per spike, weight of grains per spike and 1000 kernels weight. Grain yield was negatively and significantly correlated with time to heading.

Shah *et al.* (2006) used fifteen wheat genotypes and data were recorded on some important yield related traits. Statistical analysis was carried out and the means were separated by the LSD test. Significant differences were observed among the genotypes for the number of productive tillers m^{-2} and grain yield. However, the differences were not significant for the characters of grains number per spike, spikelets number per spike, length of spikes and weight of 1000 kernels. Productive tillers m^{-2} showed significant and positive relationship with wheat grain yield. However, its correlation was significantly negative with grains number per spike, length of spikes and weight of 1000 kernels. Correlations of spikelets number per spike with productive tillers number per metre square and length of spikes were significantly positive. UP-262 excelled in performance for grain yield and 1000-grains weight (seed index value) and its use in future breeding program is recommended.

Hartwig *et al.* (2007) reported that the genotypic, phenotypic and environmental correlation coefficients between the traits for grain yield. For all
populations, the single correlations indicated that the selection of higher yielding plants could be performed by indirect selection for the number of fertile tillers number per plant.

Kara and Akman (2007) studied the relationship between grain yield and yield characters of wheat. The positive interrelationship of grain yield with height of the plant, 1000-grains weight (seed index value) and hectoliter weight was recorded, and negatively associated with length of spikes. The relationship between grain yield and grains number per spike and weight of grains number per spike was non-significant and negative.

Kashif *et al.* (2007) reported that genotypically height of the plant, length of spikes, spikelets number per spike, grains number per spike and 1000-grains weight (seed index value) were positively and significantly correlated with grain yield while highly significantly associated phenotypically. Flag leaf area was positively but non-significantly associated with grain yield; whereas, fertile tillers number per plant was negatively and non-significantly correlated with grain yield. Height of the plant, flag leaf area, length of spikes and grains number per spike had positive direct effects on grain yield. While fertile tillers number per plant, spikelets number per spike and 1000-grains weight (seed index value) exhibited direct negative effects on grain yield. The traits having positive direct effects on grain yield are considered to be suitable selection criteria for evolving high yielding genotypes.

Koksal *et al.* (2007) determined significant positive correlation between seed yield and height of the plant (0.39) and plant density (0.29). Significant but negative association was found between test weight and plant density (-0.62), grain yield (-0.44), seed weight $spike^{-1}$ (-0.23), sedimentation and length of spikes (-0.21), spikelets number per spike (-0.19), seeds number per spike (-0.25) and seed weight $spike^{-1}$ (-0.20).

Saharan *et al.* (2007) estimated the phenotypic and additive genetic correlations between yield and its components in bread wheat populations. In the original cross, Harrier x S 308, tillers number per plant, grains number per spike and weight of grains were positively correlated with grain yield. In the derived crosses, the pattern of correlation changed due to change in linkage phase. The studies indicated that tillers number per plant and weight of grains were the main yield contributing characters. These can be used for direct selection to bring improvement in grain yield in wheat irrespective of coefficient of gene association in crosses.

MATERIALS AND METHODS:

The study was mainly aimed at investigating relationships among yield and yield traits in Mexican wheat genotypes. The experiment was laid out during 2018-19 in a three replicated Randomized Complete Block design with at Southern Wheat Research Station, Tandojam using 15 (fifteen) wheat lines. The sowing was done by drilling under the plant and row spacing of 20 and 30 cm, respectively. Randomly selected/normal looking five plants were labeled in each replication of all the genotypes tested. The following genotypes were used as breeding material:

Genotypes = Fifteen (15)

1. Mexican Line-21
2. Mexican Line-22
3. Mexican Line-23
4. Mexican Line-24
5. Mexican Line-25
6. Mexican Line-26
7. Mexican Line-27
8. Mexican Line-28
9. Mexican Line-29
10. Mexican Line-30
11. Mexican Line-31
12. Mexican Line-32
13. Mexican Line-33
14. Mexican Line-34
15. Mexican Line-35

The experimental wheat plantation was thinned **a**fter four weeks of sowing and recommended plant spacing was maintained. The following traits on the above wheat lines were investigated:

1. Plant height (cm)
2. tillers $plant^{-1}$
3. Spike length (cm)
4. Spikelets $spike^{-1}$
5. Grains $spike^{-1}$

6. Seed index (1000 grain weight g)
7. Grain yield plant^{-1} (g)

The cultural practices were performed as suggested by the Wheat Botanist, Southern Wheat Research Institute, Tandojam. The data were recorded as per the following procedures:

Plant height (cm): At the time of maturity the height of each selected plant was measured in centimeters from the surface of soil to the tip of ear-head excluding awns.

Tillers per plant: The numbers of fertile tillers produced by each selected plant were counted at the time of maturity and replication wise the data were recorded.

Spike length (cm): Length of the spike of main tiller was measured in centimeters from the base of spike to the upper most spikelets excluding awns.

Spikelets per Spike: The number of spikelets in the primary tiller of each selected plants were counted and the data were recorded as spikelets per spike.

Grains per spike: The main spike or primary tiller of each selected plant was threshed separately, number of grains was counted and replication wise data were recorded.

Seed Index (1000 grain weight in g): 1000 grains were randomly taken from each selected plant and were weighed in grams on electric balance in laboratory.

Grain yield plant^{-1} (g): After harvesting, each selected plant was threshed separately with single plant wheat thresher and cleaned in the laboratory. The grains were weighed on electric balance and yield per plant was recorded in grams.

Correlation coefficient

The collected data were analysed through New Student Statistics Software SXW Package. The analysis of variance (ANOVA) was determined as suggested by Gomez and Gomez (1984) and correlation was calculated according to Dewey and Lu (1959). Correlation coefficients were worked out between the following character combinations:

Correlating traits

1. Plant height vs tillers plant^{-1}
2. Plant height vs spike length
3. Plant height vs spikelets spike^{-1}
4. Plant height vs grains spike^{-1}
5. Plant height vs seed index
6. Plant height vs yield plant^{-1}
7. Tillers plant^{-1} vs spike length
8. Tillers plant^{-1} vs spikelets spike^{-1}
9. Tillers plant^{-1} vs grains spike^{-1}
10. Tillers plant^{-1} vs seed index
11. Tillers plant^{-1} vs yield plant^{-1}
12. Spike length vs spikelets spike^{-1}
13. Spike length vs grains spike^{-1}
14. Spike length vs seed index
15. Spike length vs yield plant^{-1}
16. Spikelets spike^{-1} vs grains spike^{-1}
17. Spikelets spike^{-1} vs seed index
18. Spikelets spike^{-1} vs yield plant^{-1}
19. Grains spike^{-1} vs seed index
20. Grains spike^{-1} vs yield plant^{-1}
21. Seed index vs yield plant^{-1}

Simple correlation coefficients (r) were calculated after Snedecor and Cochran (1980) by using the following formula.

$$\text{Correlation Coefficient (r)} = \frac{\text{Covariance}}{\text{Geometric mean of covariance}} = \frac{\sum xy}{\sqrt{\sum x^2 \; \sum y^2}}$$

$$\sum xy = \sum XY - \frac{(\sum X)(\sum Y)}{N}$$

$$\sum x^2 = \sum X^2 - \frac{(\sum X)^2}{N}$$

$$\sum y^2 = \sum Y^2 - \frac{(\sum Y)^2}{N}$$

Where:

X = Independent variable
Y = Dependent variable
N = Number of observations recorded

Regression model

In regression model, yield per plant was used as response variable (Y) along with the yield components as explanatory variable (X).

The model used was

$$Y = a + bX$$

Where "a" is constant (value of Y when X=0) and "b" is regression coefficient (slope of line) which indicates the change in Y with unit change in X. The parameters (a, b) were estimated using the method of least squares (Steel and Torrie, 1986).

RESULTS:

The experiment was conducted during 2018-19 with the objectives to study relationships among yield and yield traits in Mexican wheat genotypes. The breeding material comprised of fifteen Mexican lines (Mexican Line 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35). The mean squares corresponding to plant height, tillers plant^{-1}, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index and grain yield plant^{-1} is presented in Table 1. Mean performance of Mexican wheat lines concerning to plant height, tillers plant^{-1}, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index and grain yield plant^{-1} are is shown in Table 2. The correlation data is shown in table 3 and regression analysis is given in table 4.

The mean squares derived from analysis of variance (Tables 1) concerning to grain yield and its contributing traits of various wheat lines indicated that genotypes showed significant difference in their growth and yield traits ($P<0.05$) from each other for plant height, tillers plant^{-1}, spike length, spikelets spike^{-1}, grains spike^{-1}, seed index and grain yield plant^{-1}. The significance of differences in growth and yield traits of wheat genotypes might be the genetic influence corresponding to genetic makeup of parental material of these wheat lines.

Table 1: Mean squares derived from ANOVA for grain yield and its contributing traits of wheat genotypes

Source of Variation	Df	Plant height	Tillers plant^{-1}	Spike length	Spikelets spike^{-1}	Seeds spike^{-1}	Seed index	Grain yield plant^{-1}
Replications	2	0.283	0.691	0.208	1.176	8.452	1.048	0.184
Genotypes	14	282.14**	46.898**	2.882**	19.170**	231.209**	90.517**	35.999**
Error	28	0.378	0.234	0.040	0.262	5.435	1.639	0.139

** = Significant at 1% probability level.

Mean performance of wheat genotypes

The plant height of Mexican lines was significantly different ($P<0.05$) from each other and Mexican Line-25 produced plants of maximum height (116.13 cm), followed by Mexican Line-25 (107.93 cm), Mexican line-33 (99.412 cm) and Mexican line-26 (99.22 cm). The lowest plant height (85.20 cm) was recorded in Mexican line-35 (Table 2).

The tillering capacity of different wheat lines was significantly different ($P<0.05$) and the tillers plant^{-1} was found to be mostly influenced by genetic material, as the maximum tillers plant^{-1} (20.60) were observed in Mexican line-25, followed by Mexican line-28 (14.27 tillers plant^{-1}), Mexican line-33 (11.20 tillers plant^{-1}) and Mexican line-24 (10.67 tillers plant^{-1}); while the lowest number of tillers plant^{-1} (6.07) were recorded in Mexican line-34 (Table 2).

The spike length was significantly varied ($P<0.05$) among Mexican lines and maximum spike length (13.12 cm) were noted in Mexican line-30, followed by Mexican line-26 (12.21 cm), Mexican line-32 (12.01 cm) and Mexican line-23 (11.49 cm); while the lowest spike length (9.65 cm) was recorded in Mexican line-25 (Table 2).

The varietal response to number of spikelets spike^{-1} in wheat was significantly different (P<0.05) and maximum spikelets spike^{-1} (22.07) was equally noted in Mexican line-26 and Mexican line-30, followed by Mexican line-34 and Mexican line-35 (20.07); while the lowest number of spikelets spike^{-1} (13.73) was recorded in Mexican line-23 (Table 2).
The wheat lines varied significantly (P<0.05) for the number of seeds spike^{-1} and highest seeds spike^{-1} (62.27) were obtained in Mexican line-25, followed by Mexican line-35 (61.40), Mexican line-33 (59.53) and Mexican line-24 (58.87); while the lowest number of seeds spike^{-1} (39.53) was achieved in Mexican line-26 (Table 2).

The varietal effect of wheat varied significantly (P<0.05) for the seed index and seed index value was highest (54.25 g) in Mexican line-31, followed by Mexican line-21 (53.67 g), Mexican line-30 (53.43 g) and Mexican line-32 (52.84 g); while the lowest seed index value (36.40 g) was noted in Mexican line-22 (Table 2).

The Mexican lines used as breeding material produced significantly different yield performance (P<0.05) and Mexican Line-25 produced maximum grain yield plant^{-1} (23.38 g), followed by Mexican Line-28 (23.15 g), Mexican line-32 (21.43 g) and Mexican line-29 (21.39 g). However, the lowest grain yield plant^{-1} (13.79 g) was recorded in Mexican line-23 (Table 2).
The results showed that Mexican Line-25 showed its superiority in plant height, tillering capacity, seeds spike^{-1} as well as in grain yield plant^{-1}; and regardless the growth performance of wheat lines, Mexican Line-28 and Mexican Line-32 also showed most promising results for grain yield plant^{-1} (Table 2)

Table 2: Mean performance of wheat genotypes in regards to yield and its contributing traits

Variety	Plant height (cm)	No. of Tillers plant^{-1}	Spike length (cm)	No. of Spikelets spike^{-1}	No. of seeds spike^{-1}	Seed index (g)	Grain yield plant (g)
1. Mexican Line-21	91.20	6.27	10.39	17.80	53.93	53.67	14.56
2. Mexican Line-22	107.93	7.20	10.46	14.73	48.93	36.40	18.01
3. Mexican Line-23	95.93	6.00	11.49	13.73	42.20	48.09	13.79
4. Mexican Line-24	75.00	10.67	11.05	18.47	58.87	51.93	18.05
5. Mexican Line-25	116.13	20.60	9.65	18.07	62.27	39.21	23.38
6. Mexican Line-26	99.22	6.40	12.21	22.07	39.53	51.08	15.19
7. Mexican Line-27	86.32	7.93	9.93	17.93	51.60	48.73	12.63
8. Mexican Line-28	92.64	14.27	10.40	18.20	39.67	48.59	23.15
9. Mexican Line-29	93.00	6.67	11.43	16.25	40.07	48.53	21.39
10. Mexican Line-30	98.73	7.80	13.12	22.07	58.73	53.43	14.32
11. Mexican Line-31	87.87	6.93	9.73	18.07	58.40	54.25	17.09
12. Mexican Line-32	91.87	7.80	12.01	14.07	39.87	52.84	21.43
13. Mexican Line-33	99.41	11.20	11.44	18.33	59.53	47.50	15.52
14. Mexican Line-34	95.40	6.07	10.72	20.07	51.87	40.37	15.56
15. Mexican Line-35	85.20	8.60	11.41	20.07	61.40	49.83	18.44
S.E.±	*0.5019*	*0.3954*	*0.1647*	*0.4181*	*1.9036*	*1.0455*	*0.3049*
LSD 0.05	*1.0291*	*0.8099*	*0.3373*	*0.8563*	*3.8993*	*2.1416*	*0.6245*

Correlation

Plant height v/s Spike length
The correlation analysis (Table 3) demonstrates the association between various growth and yield traits and it was observed that the interrelationship between plant height and tillers plant^{-1} revealed negative and significant correlation (r=-0.3951**), referring as increase in the plant height decreased the tillers plant^{-1} significantly.

Plant height v/s spike length

Plant height and spike length were negatively correlated (r= -0.0491^{NS}) with each other, revealing that with increase in plant height, the spike length of wheat lines was decreased significantly i.e. taller plants did not produce longer spikes.

Plant height v/s spikelets spike^{-1}

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Plant height and spikelets spike^{-1} were negatively but insignificantly (P>0.05) correlated with each other (r= -0.0652^{NS}), suggesting that with the increase in plant height, the spikelets spike^{-1} decreased slightly.

Plant height v/s grains spike^{-1}

There was a negative but insignificant (r= 0.0216^{NS}) correlation between the plant height and number of grains spike $^{-1}$, which indicated that with increasing the plant height, the grains spike $^{-1}$ were slightly decreased.

Plant height v/s seed index

The interrelationship between plant height and seed index was highly significant (r= -0.6428**) in negative direction. It means as the plant height increased the seed index was decreased significantly.

Plant height v/s Yield plant^{-1}

There was an inverse association between plant height and grain yield plant^{-1} showed negative and insignificant correlation (r= -0.2099^{NS}), revealing that with the increase in plant height, the grain yield plant^{-1} decreased.

Tillers plant^{-1} v/s Spike length

Tillers plant^{-1} and spike length association revealed negative and significant correlation (r= -0.3585**), which suggested that with increasing tillers plant^{-1} spike length in Mexican lines was decreased.

Tillers plant^{-1} v/s Spikelets spike^{-1}

The correlation between tillers plant^{-1} and spikelets spike^{-1} showed positive but insignificant (P>0.05) association (r= 0.0704^{NS}). This emphasizes that as tillers plant^{-1} increased, the spikelets spike^{-1} remain3ed almost unaffected.

Tillers plant^{-1} v/s Grains spike^{-1}

Interrelation between tillers plant^{-1} with grains spike^{-1} showed positive and significant correlation (r= 0.0.3241*). It means as the tillers plant^{-1} increased, the grains spike^{-1} also increased.

Tillers plant^{-1} v/s seed index

These two traits were negatively and significantly (P<0.05) correlated with each other (r= 0.3265^{NS}), showing that as the tillers plant^{-1} increased the seed index decreased significantly.

Tillers plant^{-1} v/s grain yield plant^{-1}

The association of tillers plant^{-1} and grain yield plant^{-1} showed that correlation between tillers plant^{-1} and grain yield plant^{-1} was positive and highly significant (r= 06223**). This indicates that with increase in tillers plant^{-1} there was a significant increase in the grain yield plant^{-1}.

Spike length v/s spikelets spike^{-1}

The spike length and spikelets spike^{-1} revealed positive but insignificant (P>0.05) correlation with each other (r=0.2577^{NS}) emphasizing that as the spike length increased, a marginal increase in the grains spike^{-1} was recorded (Table-3).

Spike length v/s grains spike^{-1}

Correlation coefficient revealing relationship of spike length with grains spike^{-1} was positive and insignificant (r=0.2327^{NS}). This suggested that with increasing spike length, the grains spike^{-1} also increased marginally.

Spike length v/s seed index

The data in relation to correlation coefficient indicated that spike length had positive but significant (P<0.05) correlation with seed index (r= 0.3692**). This association shows that as spike length increased, the seed index was improved significantly.

Spike length v/s grains yield plant^{-1}

The correlation coefficient regarding relationship of spike length with grain yield plant^{-1} was positive and significant (r=0.3291*). This indicated that with increasing spike length, the grain yield plant^{-1} also increased significantly.

Spikelets spike^{-1} v/s grains spike^{-1}

The correlation in regards to interrelationship between spikelets spike^{-1} and grains spike^{-1} had positive and highly significant correlation (r= 0.3642**). This indicated that with increasing number of spikelets spike $^{-1}$ in wheat genotypes, the grains spike^{-1} increased significantly (Table-3).

Spikelets spike^{-1} v/s Seed index

The correlation coefficient revealing that relationship of spikelets spike^{-1} with seed index was positive but insignificant (r= 0.1936^{NS}). This suggested that with increasing spikelets spike^{-1}, the seed index was marginally increased.

Spikelets spike^{-1} v/s grain yield plant^{-1}

The correlation coefficient indicates positive but insignificant (P>0.05) correlation (r= 0.2396^{NS}) between spikelets spike^{-1} and grain yield plant^{-1} which suggested that with the increase in spikelets spike^{-1} of wheat genotypes, the grain yield plant^{-1} was also increased but in minor amounts.

Seeds spike^{-1} v/s Seed index^{-1}

The correlation coefficient indicates negative and insignificant (P>0.05) correlation (r= -0.0471^{NS}) between seeds spike^{-1} and seed index which suggested that with the increase in grains spike^{-1} of wheat genotypes, the seed index decreased to some extent.

Grains spike^{-1} v/s grain yield plant^{-1}

There was a positive but insignificant (P>0.05) correlation (r= 0.1634^{NS}) between the seeds spike^{-1} and grain yield plant^{-1}, which indicated that with increasing the grains spike^{-1}, the grain yield plant^{-1} increased to some extent (Table-3).

Seed index v/s grain yield plant^{-1}

The correlation coefficient showed that seed index had positive but insignificant (P>0.01) correlation with grain yield plant^{-1} (r= 0.2276^{NS}). This association shows that with increasing seed index value, there was a positive impact on the grain yield plant^{-1} but this effect was not so pronounced.

Table-3 Correlation (r) coefficients among various traits in wheat cultivars

Character	Plant height	Tillers plant^{-1}	Spike length	Spikelets spike^{-1}	Seeds spike^{-1}	Seed index
Tillers plant^{-1}	-0.3951**					
Spike length	-0.0491^{NS}	-0.3585**				
Spikelets spike^{-1}	-0.0652^{NS}	0.0704^{NS}	0.2577^{NS}			
Seeds spike^{-1}	-0.0216^{NS}	0.3241*	0.2327 ^{NS}	0.3642**		
Seed Index	-0.6428**	-0.3265*	0.3692**	0.1936^{NS}	-0.0471^{NS}	
Yield plant^{-1}	-0.2099^{NS}	0.6223**	0.3291*	0.2396 ^{NS}	0.1634^{NS}	0.2276^{NS}

* = Significant at 0.05 probability level
** = Significant at 0.01 probability level
NS = Non-Significant

Regression analysis

Grain yield *vs* plant height

The regression model was developed as suggested by Steel and Torrie (1986). The correlation coefficient (r= -0.2099) suggested some decrease in wheat grain yield with increasing plant height; and coefficient of determination (r^2 = 0.0218) suggested that 2.18 percent variation in grain yield was contributed by the variation in plan height; while the correlation coefficient (b) indicated that with each centimeter increase in plant height, 7.52 kg grain yield was decreased.

Grain yield *vs* tillers plant^{-1}

The correlation coefficient (r=0.6223**) indicated significant increase in grain yield of wheat genotypes with increase in tillers plant^{-1}; and coefficient of determination (r^2 =0.3730) suggested that 37.30 percent increase in grain yield was described by tillers plant^{-1}. The correlation coefficient (b) indicated that with each increase in tillers plant^{-1}, 54.42 kg grain yield was increased.

Grain yield *vs* spike length

The correlation coefficient (r=0.1991^{NS}) showed insignificant (P>0.05) effect on grain yield of wheat genotypes due to increase in spike length; and coefficient of determination (r^2=0.0173) describes that 1.73 percent variation in grain yield was linked with the change in spike length. The correlation coefficient (b) showed that with each centimeter increase in spike length, 69.32 kg increase in grain yield was expected.

Grain yield *vs* spikelets spike^{-1}

The correlation coefficient ($r=0.2396^{NS}$) for grain yield *vs* grains spike^{-1} indicated positive but insignificant relationship between these traits; while coefficient of determination ($r^2=0.035$) indicated that 3.50 percent variation in grain yield was guided by the variation in spikelets spike^{-1}. The correlation coefficient (b) indicated that with each spikelet spike^{-1} increase, 31.39 kg increase in grain yield was described.

Grain yield *vs* grains spike^{-1}

The correlation coefficient ($r=0.1634^{NS}$) for grain yield *vs* grains spike^{-1} indicated positive but insignificant association between these traits; while coefficient of determination ($r^2=0.0063$) indicated that 0.63 percent variation in grain yield was guided by the variation in grains spike^{-1}. The correlation coefficient (b) indicated that with each increase in grains spike^{-1}, 6.31 kg increase in grain yield was suggested.

Grain yield *vs* grains spike^{-1}

The correlation coefficient ($r=0.2276^{NS}$) for grain yield *vs* seed index showed positive but insignificant association between these parameters; and coefficient of determination ($r^2=0.0297$) indicated that 2.97 percent change in grain yield of wheat genotypes was associated with the change in seed index. The correlation coefficient (b) indicated that with one gram increase in seed index, 14.14 kg grain yield was increased.

Table 4: Correlation coefficient (b) and coefficient of determination (r^2) for grain yield plant^{-1} vs other components of wheat genotypes

Contributing/associated variables	Correlation (r)	Correlation Coefficient (b)	Coefficient of determination (r^2)
Plant height vs grain yield plant^{-1}	-0.2099^{NS}	-0.0752	0.0218
Tillers plant vs grain yield plant^{-1}	0.6223**	0.5442	0.3730
Spike length vs grain yield plant^{-1}	0.1991^{NS}	0.6932	0.0173
Spikelets spike^{-1} vs grain yield plant^{-1}	0.2396^{NS}	0.3139	0.0355
Seeds spike^{-1} vs grain yield plant^{-1}	0.1634^{NS}	0.0631	0.0063
Seed index vs grain yield plant^{-1}	0.2276^{NS}	0.1414	0.0297

Discussion:

Fifteen Mexican wheat lines were evaluated to study relationships among yield and yield traits; the breeding material comprised of Mexican Line 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 and 35). The achieved results are discussed in this chapter.

The present study have suggested significant difference in yield traits ($P<0.05$) among Mexican wheat lines. The significance of differences in growth and yield traits of wheat genotypes might be the genetic influence corresponding to genetic makeup of parental material of these wheat lines. The Mexican lines used as breeding material produced significantly different yield performance ($P<0.05$). Mexican Line-25 produced maximum yield performance, followed by Mexican Line-28, Mexican line-32, Mexican line-29 and lowest yield plant^{-1} was recorded in Mexican line-23. The Mexican Line-25 showed its superiority in plant height, tillering capacity, seeds spike^{-1} as well as in grain yield plant^{-1}. Mexican Line-28 and Mexican Line-32 also showed most promising results for grain yield plant^{-1}. Similar results have been reported by Safeer-ul-Hassan *et al*. (2005) who found that the genotypes differed highly significantly for all the traits such as spikelets per spike, plant height, grains per plant, grain weight per spike, 1000-grain weight and spike length grain yield. Similarly, Tabbal and Fraihat (2012) concluded that more tillers and grain yield are major yield contributing factors in selecting high yielding wheat cultivars. Moucheshi *et al.* (2013) showed that spike weight plant^{-1} was the most important variable contributing to wheat grain yield variation, while, grain weight spike^{-1} and the genotypes used in this study varied significantly in yield and its components.

The study further showed significant and positive (P<0.05) correlation for tillers plant^{-1} *vs* grains spike^{-1} (r=0.3241*), tillers plant^{-1} *vs* grain yield plant^{-1} (r= 0.6223**), spike length *vs* seed index (r= 0.3692**), spike length *vs* grains spike^{-1} (r=0.3291*) and spikelets spike^{-1} *vs* grains spike^{-1} (r= 0.3642**). However, there was negative and significant (P<0.05) association was recorded for plant h eight *vs* spike length (r= -0.3951**), plant height *vs* seed index (r= -0.6428**) and tillers plant^{-1} *vs* spike length (r= -0.3585**). These results are in accordance with those of Gupta *et al*. (2002) concluded that the length of main ear per plant, number of tillers per plant and number of spikes per plant exhibited positive and were highly and significantly correlated with grain yield. Kashif *et al*. (2004) reported that phenotypically and genotypically plant height, spike length, spikelets spike^{-1}, grains spike^{-1} and 1000-grain weights were positively and significantly correlated with grain yield; while fertile tillers per plant, spikelets per spike and 1000-grain weight exhibited negative direct effects on grain yield. Mehmet and Yildirim (2006) reported positive and significant correlation was found between yield and plant height, grain number per spike, grain weight per spike and 1000 kernels weight. Kashif *et al.* (2007) reported that genotypically plant height, spike length, spikelets per spike, grains per spike and 1000-grain weight were positively and significantly correlated with grain yield while highly significantly associated phenotypically. Flag leaf area was positively but non significantly associated with grain yield; whereas, fertile tillers per plant was negatively and non-significantly correlated with grain yield. Akram *et al.* (2008) revealed positive correlations for number of spikelets per spike, number of grains per spike and 1000 grain weight with grain yield at both genotypic and phenotypic levels. Anwar *et al*. (2009) observed that grain yield plant^{-1} was positively and significantly correlated with number of tillers plant^{-1}and days to maturity at genotypic level but non-significantly correlated at phenotypic level. Mollasadeghi *et al.* (2011) showed that the grain yield has a positive correlation (0.527**) with seed index, while Rashidi (2011) revealed a significant and positive relationship of grain yield with traits such as number of fertile tiller, grains/spike, biomass and harvest index. Khan *et al.* (2014) showed that grain filling rate was found positively correlated (0.652**) with grain yield. Likewise, the findings of the present research are in similarity with results reported by these workers. However, some contradiction existed that might be due to the varietal and environmental influence; moreover, the genetic material used by different past workers may differ in crop performance for different traits due to genetic makeup of parental material used for different genotypes. Junejo (2014) used wheat genotypes NIA Amber, Sarsabz, Mehran-89, TJ-83, Imdad-2005, TD-1, NIA Sonahri and Kiran for correlations studies and indicated that there was a positive and significant correlation between tillers plant^{-1} and grain yield plant^{-1} (0.9744**), spike length and spikelets spike^{-1} (0.5897**), spike length and grains spike^{-1} (0.6491**), spike length and grain yield plant^{-1} (0.5535**), spikelets spike^{-1} and grains spike^{-1} (0.5509**), spikelets spike^{-1} and seed index (0.5942**), spikelets spike^{-1} and grain yield plant^{-1} (0.4834*), grains spike^{-1} and grain yield plant^{-1} (0.4506*). Khan Hussain *et al.* (2014) reported that phonotypic and genotypic correlation coefficient of grain yield with number of spikelets spike^{-1}, days to maturity, number of tillers m^{-2} and number of grains spike^{-1} was observed positive and significant whereas plant height and spike length was found has deterrent traits for grain yield improvement because those characters showed negative association with grain yield.

The findings of the study further showed that coefficient of determination (r^2) have suggested 2.18% decrease in grain yield with increasing plant height; and 37.30 percent increase in grain yield was described by increase in tillers plant^{-1}; while 1.73% variation in grain yield was linked with spike length variation. Similarly, 3.50% variation in grain yield was guided by the variation in spikelets spike^{-1} and 0.63 percent variation in yield was guided by change in grains spike^{-1}; while 2.97% change in grain yield was associated with the change in seed index. The above research findings are in concurrence to those of Al-Tabbal and Al-Fraihat (2012) who evaluated the performance of twenty three promising wheat genotypes using correlations, and partial regressions were estimated for all the traits. Analysis of variance revealed significant differences among the genotypes for all the characters. It was concluded that more fertile tiller number and kernel weight of main spike were major yield contributing factors in selecting high yielding wheat cultivars. The regression studies concluded that more tiller number and kernel weight of main spike are major yield contributing factors in selecting high yielding wheat cultivars. Fellahi *et al.* (2013) reported that tiller number, seed index, biological yield and harvest index may be used an effective selection criterion to improve genetic yield potential of bread wheat genotypes. Gelalcha and Hanchinal (2013) reported that about 94% of the variability in the grain yield was determined by the component traits indicated the presence of perfect matching between the component traits and the grain yield; hence, could be used as selection indices for yield improvement. Hannachi *et al.* (2013) reported from regression studies that both above ground biomass and harvest index could be a criterion to select high-yielding genotypes in breeding durum wheat programs. Meyari *et al.* (2013) concluded that seed weight spike^{-1}, harvest index and seed spike^{-1}, in normal condition and seed spike^{-1}, thousand kernel weights and harvest index in source restriction condition could be used as a standard selection method in breeding programs. Moucheshi *et al.* (2013) showed that spike weight plant^{-1} was the most important variable contributing to wheat grain yield variation, while, grain weight spike^{-1} and leaf area were also important variables accounting for wheat grain yield variation.

Therefore, spike weight plant^{-1} of flag leaf can be used as selection criteria in breeding programs. Shahryari *et al*. (2013) indicated that traits such as 1000 grain weight and spike number per m^2 could be considered criteria for selecting productive bread wheat lines.

Conclusions

- The Mexican lines used as breeding material produced significantly different yield performance (P<0.05).
- Mexican Line-25 produced maximum yield performance, followed by Mexican Line-28, Mexican line-32, Mexican line-29 and lowest yield plant^{-1} was recorded in Mexican line-23.
- The Mexican Line-25 showed its superiority in plant height, tillering capacity, seeds spike^{-1} as well as in grain yield plant^{-1}.
- Regardless the growth performance of wheat lines, Mexican Line-28 and Mexican Line-32 also showed most promising results for grain yield plant^{-1}
- The coefficient of determination (r^2) suggested tillers plant^{-1} as the major factor to change grain yield plant^{-1} of wheat genotypes (37.30%).

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