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Modeling the Growth and Yield of Pearl Millet (*Pennisetum glaucum*) Crop

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ABSTRACT

Millet is one of the important foods for Pakistan. It has many uses in food products as well as a forage crop. Crop models are useful in agro-meteorological research for checking scientific hypotheses, highlighting where information is missing, arranging data, and analyzing transversely disciplines. To envisage crop presentation in areas where the crop has not been tested earlier or not planted below mainly constructive situations, crop growth models are used. Pearl millet has advanced nitrogen use efficiency than numerous other crops because raising the velocity of nitrogen fertilization does not forever go with a subsequent enlargement in grain yield. Considerable results among several growth characters of pearl millet for example forage yield and plant height increased by increasing nitrogen fertilization rates. The increase in yield with increased nitrogen levels was mainly associated with increased stem diameter, number of leaves/plants, and plant height. Considerable results among several growth characters of pearl millet for example forage yield and plant height increased by increasing nitrogen fertilization rates. The increase in yield with increased nitrogen levels was mainly associated with increased stem diameter, number of leaves/plants, and plant height. Results showed that more application of nitrogen fertilizer produced more panicle weight, which in result produced more yield and biological productivity, respectively. Results showed that more application of N fertilizer produced more GY, which in result produced more straw yield. Results showed that more application of nitrogen fertilizer produced more thousand-grain weight, which in result produced more grain. it is concluded that nitrogen levels and different cultivars have a significant effect on the growth and yield of pearl millet.

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INTRODUCTION

Pearl millet is classified into the Poaceae family and genus Pennisetum with the scientific name *Pennisetum glaucum*. There are some common names of pearl millet such as bulrush millet, cattle millet, bajra. There are about 140 humid grass species integrated into the genus Pennisetum (Gulia et al., 2007). Pearl's first domestication happened in the Sahel zone of West Africa about 2000 to 2500 BC ago and later spread to southern Asia (Manning et al., 2010). Kumar et al., (2016) explained that pearl millet is diploid, and cross-pollination occurred in pearl millet about 75%. Pearl millet holds a high photosynthetic proficiency and biological productivity due to its C4 carbon fixation. It is cultivated on about 25 to 36.9 million hectares all over the World and it is vital and healthy full of nutrients cereal (Yusuf et al., 2012).

The raising of new novel pearl millet cultivars for huge kernels productivity due to acknowledgment of the long-termed observations of pearl millet for kernels productivity, various research schemes are in progress (Obeng et al., 2012). Pearl millet hybrids diversity can be used for further breeding purposes for the growth of plants lead to exampled grain production (Khairwal et al., 2007). To produce dwarf hybrids investigation for grain has focused on suitable row distance controlling sowing time (Pale *et al*., 2003), and well-shaped environment conditions (Maman et al., 2006). Dwarf varieties are suitable for grazing but low in kernels yield and heightened hybrids varieties for high yield of grains (Hancock, 2009). Most domesticated types of pearl millet are drought stress-tolerant and can yield under low precipitation (200-250 mm) (Bidinger and Hash, 2003). Dera (2014) reported that alongside contributing food for people, millet stem is utilized for an extensive series of purposes which involve, fence stakes and hatchings, the development of hut walls, and the creation of baskets, mats umbrellas, and brooms. It is ranked 6th in grains in the world and the erstwhile Soviet Union, India, Egypt, and Africa pearl millet is a vital component of the feast (Singh and Raghuvanshi, 2012). Pearl millet is also a staple food and grows for both productivities of grains and productivity of fodder in developing areas (Rani et al., 2011). Pearl millet's genetic studies can function as the conventional species for its importance of fodder and grain crop (Gulia et al., 2007).

The prime idea of research is "Modeling the development and production of pearl millet crop". The effect of attributes of climate change like carbon dioxide (CO_2), temperature (°C), and precipitation on crop growth and grain production are acknowledging by adopting crop models. There are recently developed models like explanatory models, stochastic models, empirical models, optimizing models, and mechanistic models.

Role of nitrogen

Nitrogen is a vital necessary nutrient for more reliable plant growth. It plays a significant part in the production of grains. Through the application of nitrogen at various plant growth stages, the yield of crops increases. Parsad et al., (2014) explained that a fundamental nutrient required for pearl millet absolutely improves the growth contributing traits, length, and diameter of panicle, the weight of panicle, no. of kernels, and their weight per panicle, and lastly increase the yield is nitrogen. Chouhan et al., (2015) reported that nitrogen improves leaf and stem extension quickly that consequently boosts the quality and yield. Numerous nutrients mutually with the suitable ratio of N: P: K enhances optimum yield (Obeng et al., 2012).

Suitable application of nitrogen is a crucial perspective on cost-effective supervision of nitrogen-based fertilizers, degeneration of soil vitality, and addition of noxious nitrates in fodder crops that are lethal to animals that occurred because of excess usage of nitrogen fertilizer.

Effect of cultivars

The yield of a crop has been prominently influenced in defining manners by cultivars. Cultivars exhibit more vigorous yield as contrasted to local races. Seldom local races/varieties exhibit higher yield than cultivars. Various cultivars exhibit diverse plant stature, leaf area, shoot weight and show resistance against diseases and insects/pests, and produce different levels of yield too. (Yusuf et al., 2012; Singh et al., 2017).

Modeling

Rauff and Bello (2015) told that the crop models primarily utilized for, data management and studying crosswise systems in agronomic meteorological research analyze methodical hypotheses, indicate where data are scattered. To imagine crop performance in regions where the crop has not been either studied before or not experimented with under defined conditions than there the crop models (previously generated) might be implemented.

For determination, the accuracy and productivity of pearl millet's genotypes crosswise in the field than CERES millet model, CROPSYST, Pm-Models should be exclusively implemented. For the physicochemical method, the consequence of environmental components on the production of the contemporary crop model incorporates the combination of certain algorithms. Above the preceding decades, numerous decision support tools (DSTs) have been generated, they extend from manageable favorite decision charts to advanced computer models. For the invention of excellent knowledge relevant to agriculture, agriculture decision support equipment (DSTs) from the received details and data attention to climate, soil, and crop superintendents should be practiced. However, the Sahelian millet-base method, at that point, is different from the general soil and water crop model in the case of agricultural resolution for crops, in different areas as well (Akponikpe et al., 2014).

Crop models of DSSAT have reset, designed to support additional expert incorporation of well-organized inventiveness, utilization, documentation, and assurance. Great necessary aspects of DSSAT presented while, it expanded models for improving attitudes, the report is logical and a voluntary edge in support of both modules (Jones et al., 2003). Global organization of scientists is running (International Benchmark Sites Network for Agro-technology Transfer) project which produced DSSAT to secure the smooth function of crop models in system progress via agronomic research.

MATERIALS and METHODS

Experimental site:

The experiment of the current research was carried out to determine the response of cultivars pearl millet and different nitrogen levels during 2018 A.C. at Bahauddin Zakariya University (BZU), Multan, Pakistan.

Analysis of soil:

The constitution of the soil was clay-silt-loam, and the texture of soil comprises 24% of sand, 47% of silt, and 24% of clay. P^H noted before planting seeds during land preparation was 8.9, Electrical conductivity was 3.21/DSM, staple stock content was 0.82 %, N was 0.037 %, available P was 4.89ppm, and available K was 263 ppm.

Climatic Data:

The origin of where the standard meteorological report was received was Central Cotton Research Institute, Multan. Daily climate recordings for the experimental site, for 2018 were summed up by the draft. In the summer season, daily maximum and minimum up-air temperatures are listed as 28.00°C and 38.01°C. The medium maximum and minimum temperature during that season was 28.9°C and 35.9°C sequentially. Sunshine ampere-hours were from 1.00 to 10.00. Cumulative precipitation through that period was 2mm. That precipitation took placed throughout August but throughout the vegetative phase, there was no precipitation took place. The corresponding humidity was between 82.7 and 67.6 %.

Treatments and experimental designs:

A: Pear Millet cultivars

1- Royal-seed Hp-50
2- Agri-greens Hp-50
3- Badshah

B: Nitrogen levels

No= 0kg/ha

N_1= 45kg/ha

N_2= 90kg/ha

N_3= 135kg/ha.

For that experimental layout, randomized complete block design (RCBD) is utilized by having the factorial segmented arrangement with 3 replications. The sowing date of the crop is 20 August 2018 and harvested on 25 November 2018. The nitrogen applied in the soil was 135kg per hectare. The first dose of nitrogen and first irrigation was applied on 06 September 2018, the second dose of nitrogen and second irrigation was applied on 20 September 2018, the third dose of nitrogen and third irrigation was applied on 12 October 2018, and the fourth dose of nitrogen and fourth irrigation was applied on 25 November 2018.

Crop husbandry:

Irrigation was done on the site ten days before sowing, for land preparation three-time cultivator and two-time planking were applied on land site after the land site got into wattar state, on 20 August 2018, the sowing of pearl millet cultivars was accomplished with a seed rate of 1.2 kg/ha and R-R space of 15cm by utilizing a hand drill in the kera method. The crop was implanted on rows comprising a distance of 15cm (R-R). Weed's execution was finished manually when needed.

Tube-well water was utilized as a reservoir for irrigation. Overall, four irrigations application was exercised. During land, preparation phosphorus was applied in the state of DAP as 120kg/ha. Nitrogen was utilized at the scale of No= 0kg/ha, N1= 45kg/ha, N2= 90kg/ha and N3= 135kg/ha. For the whole treatment, all early agronomic methods including plant preservation, weeding, etc. were kept conventional.

Measurements noted:

During the trial of the research, the following computations were recorded.

1. Plant height

2. Tillers per plant
3. Plants per plot
4. Leaf area index
5. Panicle width (cm)
6. Kernels per panicle
7. Panicle weight (g)
8. One kernel weight (g)
9. Grain yield (kg ha-1)
10. Thousand-grain weight (g)
11. Biological yield (kg ha-1)
12. Harvesting index (%)

Sampling:

The last harvest with five plant harvesting was performed to note computations in the attention of growth and production yield. At 14 days period, five plants were collected from each plot. The electronic balance was utilized for computing the fresh weight of each sample. A dry-of-relevant sub-sample with the constant temperature at 75°C was performed by adopting an oven.

Plant height

At 30 days interval, the plant height was measured by adopting a measuring tape. The height of three randomly appropriate plants from every plot was measured from the surface of soil approaching the peak of the plant and then the mean is computed.

Tillers per plant

From three randomly chosen plants, Tillers per plant were counted of selected plants in each plot and then median.

Plants per plot

Plants per plot computed by counting all plants in each plot and then take the average.

Leaf area index

The Leaf area index was computed by dividing the total leaf area (m^2) per plant by the ground area (m^2) covered by a single plant.

Harvesting components

The process adopted for estimating data on different notes of physiological and agronomic characteristics is presented as:

Panicle width (cm)

Panicle width of selected plants was measured by the metering rod of all panicles possessed by the selected plant and then median.

Kernels per panicle

Kernels per panicle were assessed by counting kernels of each panicle of selected plants and then median.

Panicle weight (g)

Panicle weight was computed by the electronic weighing balance of selected plants panicles and then median.

One kernels weight (g)

Kernel's weight was computed by the electronic weighing balance of selected plants and then median.

Grain yield (kg/ha)

Grain yield computed by multiply grain weight in kg per meter square by 10000.

1000-Grain weight (g)

1000 grains were computed by the electronic weighing balance of selected plants and then median.

Biological yield (kg ha^{-1})

Biological yield (BY) was computed in kg after harvesting as total dry weight per $1m^2$ multiply by 10000.

Harvesting index (%)

The harvesting index is estimated by the weight of grain divided by the total weight of above-ground biomass.

RESULTS

Results gathered from the research are described as below:

The highest plant height 63.17 cm got from ROYAL-SEED HP-50 and 67.0 cm from N3. The smallest plant height 59.42 cm got from BADSHAH and 55.89 cm exclusive of nitrogen treatment (Table 1).

Most no. of tillers (8.12) was given by ROYAL-SEED HP-50 and 8.21 from N3, the least no. of tillers (7.00) were given by BADSHAH and 6.77 exclusives of nitrogen treatment. (Table 2)

Most no. of plants/plot (28.41) was delivered by ROYAL-SEED HP-50 and 32.69 from N3, the least no. of plants/plot (25.69) were produced from BADSHAH and 22.15 exclusive of nitrogen treatment. (Table 1)

The best leaf area index (1.309) was acquired from ROYAL-SEED HP-50 and 1.362 from N3, merest leaf area index 1.214 was acquired from BADSHAH and 1.148 exclusive of nitrogen treatment. (Table 1)

The highest panicle width (3.23 cm) got from ROYAL-SEED HP-50 and 3.31 cm from N3, smallest panicle width (2.80 cm) got from BADSHAH and 2.77 cm from exclusive of nitrogen application. (Table 1)

Most no. kernels/panicle (2938.8) was acquired by ROYAL-SEED HP-50 and 2990.1 from N3, the least number of kernels/panicle (2825.4) were provided by BADSHAH and 2804.9 exclusives of nitrogen treatment. (Table 1)

Table 1. Effect of cultivars and nitrogen levels on understudy agronomic traits

	Treatments									
	Cultivars				Nitrogen levels					
Traits	Royal seed HP 50	Agri Greens HP 50	Badshah	LSD 5%	N_0 = 0 kg ha^{-1}	N1 = 45 kg ha^{-1}	N_2 = 90 kg ha^{-1}	N3 = 135 kg ha-1	LSD 5%	Interaction (A x B) mean
Plant Height	63.17 a	61.13 b	59.42 c	1.4	55.89 d	59.39 c	59.39 c	59.39 c	1.6177	61.263
Tillers Per Plant	8.12 a	7.37 b	7.00 c	0.142	6.77 d	7.34 c	7.68 b	8.21 a	0.164	7.5
Plants Per Plot	28.41 a	26.34 b	25.69 b	0.97	22.15 d	25.12 c	27.31 b	32.69 a	1.12	26.82
Leaf Area Index	1.309 a	1.219 b	1.214 b	0.14	1.48 d	2.04 c	2.76 b	3.62 a	0.16	12.47
Panicle width (cm)	3.23 a	2.98 b	2.80 c	0.074	2.77 d	2.89 c	3.04 b	3.31 a	0.085	3
Kernels Per Panicle	2938.8 a	2888.7 b	2825.4 c	23.23	2804.9 d	2851.1 c	2891.0 b	2990.1 a	26.83	2884.3
Panicle Weight (g).	36.95 a	34.14 b	32.29 c	0.95	28.72 d	32.50 c	36.73 b	39.91 a	1.1	34.46
One Kernel Weight (g).	5.05 a	4.94 b	4.72 c	7.2	4.27 d	4.70 c	5.09 b	5.56 a	8.32	4.9
Grain Yield (Kg Ha^{-1}).	948.00 a	886.25 b	885.83 b	12.28	865.44 d	880.56 c	925.56 b	955.22 a	14.18	906.69
Thousand Grain Weight (g).	6.14 a	5.90 b	5.85 b	0.069	5.55 d	5.79 c	6.04 b	6.48 a	0.08	5.96
Biological Yield (Kg Ha^{-1}).	1328.0 a	1301.4 b	1277.5 c	6.17	1245.61 d	1281.42 c	1314.60 b	1367.71 a	7.12	1302.3
Harvesting Index (%)	0.72 a	0.70 b	0.70 b	9.65	0.68 d	0.69 c	0.71 b	0.73 a	0.01	0.7

The highest panicle weight of (36.95 g) was received from ROYAL-SEED HP-50 and 39.91 g from N3, the smallest panicle weight (32.29 g) was received from BADSHAH and 28.72 g exclusive of nitrogen treatment. (Table 3.1)

The best one kernel weight of (5.05 g) was acquired from ROYAL-SEED HP-50 and 5.56 g from N3, the worse one kernel weight (4.72 g) acquired from BADSHAH and 4.27 g exclusive of nitrogen treatment. (Table 1)

Best grain yield 948.00 kg/ha was acquired from ROYAL-SEED HP-50 and 955.22 kg/ha from N3. The lower grain yield of 885.83 kg/ha was acquired from BADSHAH and 865.44 kg/ha exclusive of nitrogen treatment. (Table 1)

Most 1000 grain weight (6.14 g) was acquired from ROYAL-SEED HP-50 and 6.48 g from N3. The least 1000 grain weight was 5.85 g, was acquired from ROYAL-SEED HP-50 and 5.55 g exclusive of nitrogen treatment. (Table 1)

The Best biological yield of 1328.0 kg/ha was accomplished from ROYAL-SEED HP-50 and 1367.7 kg/ha from N3. The least biological yield of (1277.5 kg/ha) was accomplished from BADSHAH and 1245.6 kg/ha exclusive of nitrogen treatment. (Table 1)

The highest harvesting index 0.72 was acquired from ROYAL-SEED HP-50 and 0.73 from N3. The lowest harvesting index 0.70 was acquired from BADSHAH and 0.68 exclusives of nitrogen use. (Table 1)

Conclusions pointed out that if we enhance the utilization of nitrogen's fertilizer then it will deliver more the weight of thousand grains, which results in high harvesting index, grain yield, and biological yield, sequentially.

DSSAT-CERES-Millet model was calibrated with the most beneficial accomplished treatment nitrogen level 350 kg ha-1. Evaluation of the DSSAT-CERES-Millet model was accomplished with the rest treatments of maize experiments. The limit of the RMSE value for celebrated and assumed phonological steps like anthesis and physiological maturity day was from 0 to 1 day. Examined anthesis and maturity days were enhanced with enhancing the nitrogen fertilizer level. The principal divergence within examined and simulated for anthesis and physiological maturity was one day. The highest leaf area index value was enhanced by enhancing the nitrogen level. The examined height leaf area index was 1.48, 2.04, 2.76, and 3.62, and the simulated highest leaf area index was 1.75, 2.38, 2.95, and 3.71 for nitrogen levels 0, 45, 90, and 145kg/ha, sequentially. RMSE value 0.72, 0.57, 0.51 and 0.48 for nitrogen levels 0, 45, 90 and 145kg/ha, sequentially for highest leaf area index. Maize grain yield was enhanced by enhancing the nitrogen level.

The examined grain yield was 865.44, 880.56, 925.56, and 955.22kg/ha, and simulated was 897.13, 924.52, 945.21, and 986.28 kg ha-1 for nitrogen levels 0, 150, 250, and

350kg/ha, sequentially. RMSE value was 456.23, 387.07, 298.31, and 265.82kg/ha for grain yield. Total biomass yield was enhanced by enhancing the nitrogen level. The examined total biomass yield was 1245.61, 1281.42, 1314.60, and 1367.71kg/ha, and simulated was 1342.56, 1307.24, 1357.49, and 1405.32kg/ha for nitrogen levels 0, 45, 90, and 145 kg/ha, respectively. RMSE value was 2302.14, 2193.28, 1897.34, and 1742.62 kg/ha for total biomass. (Table 2).

Table 2. Observed and simulated results during model calibration and evaluation

Variable	**unit**	**Nitrogen levels (kg ha^{-1})**	**Observed**	**Simulated**	**RMSE***
An-thesis	day	0	38	39	1
		45	40	41	1
		90	43	44	1
		135	45	45	0
Maturity	day	0	87	88	1
		45	90	91	1
		90	93	94	1
		135	95	96	1
Max. LAI		0	1.48	1.75	0.72
		45	2.04	2.38	0.57
		90	2.76	2.95	0.51
		135	3.62	3.71	0.48
Mat. yield	kg ha^{-1}	0	865.44	897.13	456.23
		45	880.56	924.52	387.07
		90	925.56	945.21	298.31
		135	955.22	986.28	265.82
Total biomass	kg ha^{-1}	0	1245.61	1342.56	2302.14
		45	1281.42	1307.24	2193.28
		90	1314.6	1357.49	1897.34
		135	1367.71	1405.32	1742.62

*RMSE; Root mean square error

DISCUSSIONS and CONCLUSION

Plant height is a vital characteristic which undeviatingly associated with production purposes, various pearl millet varieties reveal contrast in plant height that might be because of the genetic composition of certain cultivars (Hassan et al., 2014). According to our research cultivar (v1=Royal seed hp-50) conferred higher plant height (63.17 cm) than the other two cultivars, which is approved by our experiment carried under good irrigations. Enhanced plant height with N utilization during growth was measured; the cause might be the beneficial influence of N on parameters of growth because of cell division and enlargement (Joshi et al., 2018). The contemporary research confers the equivalent outcomes, the greater appliance of nitrogen N3=135 kg/ha exhibit superior plant height (67.0 cm), than the other two cultivars; this is further published by (Nour et al., 2014).

Efficient tillers/plant performs a vital part in kernel yield of pearl millet (Chaudhari et al., 2018). These outcomes of contemporary research are the equivalent as reported by (Saifullah et al., 2011), that cultivars contain no meaningful dissimilarity in tillers/plant. Whereas the higher utilization of N with N3=135 kg/ha yields more fertile tillers/plant (8.21), these conclusions are in order with other scientists (Ayub et al., 2009; Shahin et al., 2013), who stated that fertile tillers enhanced with enhancing N utilization.

The essential base which secures effective production besides crop growth is the higher plant population and the great uniformity in the population (Afzal et al., 2018). N treatment enhances the plant population on the unit block by promoting healthy cell walls which produced excessive tillering, instant results of our research also reveal this diversity by generating a higher quantity of plants (32.69), at the superior utilization of nitrogen N3=135 kg/ha.

These effects are also confirmed by (Joshi et al., 2018). Cultivars also exhibit a slight variation in plant population in the contemporary research which is proclaimed by (Hassan et al., 2014), that variation in plant population per unit area of different pearl millet varieties is due to the contrast in seed viability or variation in 1000 grain weight.

The number of leaves/plant performs a fundamental function in overall growth because those are food industries which manufacture food by photosynthesis (Nour et al., 2014). In contemporary research cultivars exhibit slight variation in leaves/plant, while nitrogen performs an important function for improving leaf numbers which are also determined by other scientists (Ayub et al., 2009; Hassan et al., 2014; Nour et al., 2014).

Grain yield was pretty enough influenced by altering levels of nitrogen application, high grain yield was achieved by utilizing more N spreading, more grain could be due to the consolidated outcome of advancement in yield characteristics like the no. of productive tillers count per plant, panicle width plus diameter (Joshi et al., 2018). Our conclusions follow that of (Chaudhari et al., 2018), who discovered that the N component is the nutrient that chiefly enhances yield and performs an influential part in the pearl millet quality.

Moreover, Parsad et al., 2014, achieved that nitrogen is the principal nutrient demanded by pearl millet which arbitrarily improves growth characteristics, length, and diameter of panicle, test weight, number of grains/panicle, grain weight/panicle, and ultimately boost the yield. Yadav et al., (2019) also proclaimed that nitrogen represents an extraordinary part in advancing crop growth. In the present research cultivars also exhibit huge variations concerning grain yield, also confirmed by (Hassan et al., 2014), who observed that pearl millet cultivars have great variations regarding yield and quality parameters.

1000 grain weight is a symbol of yield, exhibited data proves a slight variation amongst cultivars but nitrogen utilization presents excellent differentiation as described by (Chaudhari et al., 2018), larger utilization of nitrogen provides more thousand grains weight. Thousand grains weight provided by one cultivar reported superior as correlated to other both cultivars because of more definite and big grains composed by the one cultivar. The harvesting index is improved by enhancing nitrogen utilization. Current conclusions are also in compliance with (Bacci et al., 1998), which proclaimed that the harvesting index exhibits notable variations through and exclusive of nitrogen fertilizers, harvesting index improved through improving nitrogen fertilizer application.

As a result of this experimentation, it is concluded that nitrogen levels and different cultivars have a significant effect on the growth and yield of pearl millet. Pearl millet cultivar V1 (Royal seed HP-50) performed better in this experiment. Similarly, nitrogen level N3 (135 kg/ha) produced a higher yield.

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Conflict of Interest Statement

The authors have declared that there are no competing interests.

Authors' Contributions

Muhammad Naeem Raza, Samreen Nazeer and Shehza Mubashra plan and conducted the experiment. Madad Ali, Samreen Nazeer and Anila Sadia has prepared the manuscript. Madad Ali and Samreen Nazeer finalized the manuscript.

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