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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(12): 2810-2814

www.thepharmajournal.com
Received: 20-09-2023
Accepted: 23-10-2023

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Agro-meterological indices of pearl millet under varied nutrient regimes in semi-arid climate of Haryana

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Abstract
A field study was conducted during *Kharif* seasons of 2017-18 and 2018-19 at Research Farm, Department of Agronomy, CCSHAU, Hisar to evaluate temperature-based agrometeorological indices for pearl millet sown under different combinations of nutrient sources in *pearl millet*–wheat cropping system. The experiment consisted of twelve treatments (T_1 (Control),T_2 (50% recommended NPK), T_3 (50% recommended NPK in *Kharif* and 100% recommended NPK in *Rabi*), T_4 (75% recommended NPK), T_5 (100% recommended NPK), T_6 (50% recommended NPK + 50% N through FYM in *Kharif* and recommended NPK in *Rabi*), T_7 (75% recommended NPK+25% N through FYM in *Kharif* and 75% recommended NPK dose through fertilizers in *Rabi*), T_8 (50% recommended NPK + 50% N through wheat straw in *Kharif* and 100% recommended NPK in *Rabi*), T_9 (75%recommended NPK + 25% N through wheat straw in *Kharif* and 75% recommended NPK in *Rabi*), T_{10} (50% recommended NPK+ 50% N through green manure in *Kharif* and recommended NPK in *Rabi*), T_{11} (75% rec. NPK + 25% N through green manure in *Kharif* and 75% rec. NPK in *Rabi*) and T_{12} (Farmer's Practice)) and was laid out in RCBD design with four replications. Yield attributing characters and yield of *pearl millet* were recorded highest with the application of 50% recommended NPK + 50% N through FYM in *Kharif* and recommended NPK in *Rabi*. Nutrient application from both organic manures and fertilizers resulted in delayed in 50percent flowering initiation stage.

Keywords: Pearlmillet, NPK, wheat straw, green manure, HUE

Introduction

Pearlmillet (*Pennisetum glaucum* L.) - wheat (*Triticum aestivum* L.) cropping system is the second most important cropping system of the Indo-Gangetic Plains of India. Sequential cropping resulted in more depletion of soil nutrients thus dependence on fertilizers increases (Moharana *et al.* 2017) [4]. Excessive use of synthetic fertilizers imbalance the soil's nutritional status resulting in multiple nutrient deficiencies; mainly for micronutrients diminishing soil fertility and unsustainable crop yields. Thus, there is a need to improve the current nutrient supply of soil with an integrated approach (use of both organic and inorganic sources). Integrated nutrient management practices can only fix the nutrient supply to meet the crop needs sustainably. Along with the crop demand for nutrients, abiotic factors are equally important for the growth and development of the crop. Solar radiation, temperature, and rainfall are the most important meteorological parameters that influence crop growth. The combination of these factors has a greater influence on crop growth as compared to the individual one. The interception of solar radiation and its use efficiency plays an important role in the dry matter accumulation of a crop. *Pearl millet* is a photosensitive and thermo-sensitive, long-day plant. The amount of solar radiation energy that crops intercept during their growth season is determined by the total amount of incoming radiation that crops intercept as a result of canopy development throughout their different phenological stages.

Parihar *et al*. (2005) [6] reported that increased fertilizer application had a noticeable impact on the crop's growth, yield metrics, and, ultimately on the grain yield of pearl millet. Application of 60 kg N+30 kg P_2O_5 +20 kg K_2O/ha resulted in maximum grain yield (2063.1 kg/ha) among all the treatments. Murtisankar *et al*. (2012) [5] also found that fertilizer treatments significantly influenced the grain yield of pearl *millet.* Agroclimatic indices help to evaluate the effect of agrometeorological factors at various crop stages. Fertilizer deficiency influences the growth of crop reducing the leaf area of pearl millet and intercepted photosynthetically active radiation (IPAR) while Sharma *et al*. (2000) [10] found a relationship between PAR interception and dry matter production in pearl millet.

Rathore *et al*. (2008) [9] reported that photosynthetic active radiation had a greater radiation absorption coefficient and a lower radiation transmission coefficient in 90 kg N + 45 kg P2O5/ha. Any crop's yield may be predicted using the photothermal unit idea, which offers a trustworthy indicator of the crop's development. Thus, the goal of the current study is to examine several agro-meteorological indices of pearl millet grown in Haryana's semi-arid climate under varying nutrient regimes. Using agrometeorological variables such as GDD, HTU, PTU, and HUE under various nutrient regimes, the current study aimed to predict pearl millet production.

Materials and Methods

The field research was conducted in 2017-18 and 2018-19 at Chaudhary Charan Singh Haryana Agricultural University, Hisar, to assess the association between crop growth and yield and agro-meteorological variables. The climate of Hisar (29°10' N latitude and 75°46' E longitude at an elevation of 215.2 m above mean sea level.) is sub-tropical, semi-arid with an average annual rainfall of around 450 mm of which, 70-80 per cent is received during monsoon period *i.e.*, July to September and the rest is received in showers of cyclicrains during the winter and spring seasons. Agrometeorological indices based on temperature were determined for pearl millet grown in a pearl millet–wheat cropping system under various nutrition regime combinations. The experiment was laid out in Randomized Block Design replicated four times with twelve treatments *viz*. T_1 (Control both in *Kharif* and *Rabi*), T_2 (50% recommended NPK dose through fertilizers both in *Kharif* and *Rabi*), T_3 (50% recommended NPK dose through fertilizers in *Kharif* and 100% rec. NPK dose through fertilizers in *Rabi*), T_4 (75% rec. NPK dose through fertilizers in both *Kharif* and *Rabi*), T_5 (100% rec. NPK dose through fertilizers in both *Kharif* and *Rabi*), T_6 (50% recommended NPK dose through fertilizers + 50% N through FYM in *Kharif* and recommended NPK dose through fertilizers in *Rabi*), T_7 (75% rec. NPK dose through fertilizers + 25% N through FYM in *Kharif* and 75% rec. NPK dose through fertilizers in *Rabi*), T_8 (50% recommended NPK dose through fertilizers + 50% N through wheat straw in *Kharif* and 100% recommended NPK dose through fertilizers in *Rabi*), T_9 (75% recommended NPK dose through fertilizers + 25% N through wheat straw in *Kharif* and 75% recommended NPK dose through fertilizers in *Rabi*), T_{10} (50% recommended NPK dose through fertilizers + 50% N through green manure in *Kharif* and Rec. NPK dose through fertilizers in *Rabi*), T_{11}(75% rec. NPK dose through fertilizers + 25% N through green manure in *Kharif* and 75% recommended NPK dose through fertilizers in *Rabi*) and T_{12} (Farmer's Practice in both *Kharif* and *Rabi*).

The experimental field's soil was characterized as a sandy loam with a pH of 8.1, low levels of available organic carbon and nitrogen, moderate levels of available phosphorus, and high levels of available potassium. The land was prepared with two ploughings, one planking, and irrigation before sowing. The hybrid pearl millet HHB-197 seed was sown at a depth of around 5 cm, with a plant-to-plant spacing of 15 cm and rows spaced 45 cm apart. The other practices, including irrigation, weed control, and bug and pest management, were carried out as per the CCSHAU, Hisar, recommended package of practices. To reduce yield losses, pearl millet was harvested and threshed manually Samples of the produce from each treatment were taken, and 1000 grains of pearl millet were counted and dried in an oven at 60 ^{0}C for 48 hours to record the test weight of the grain.

They were weighed after drying, and the test weight was determined by taking the mean weight of 1000 grains. After 30 days of sowing, the number of effective tillers per meter row length at five randomly selected sites within each plot was counted and calculated. The sundried produce of each treatment was tied in bundles and weighed to determine the dry matter produce (grains + straw). The grain obtained after threshing and win no wing from each treatment was weighed and noted. The straw weight was obtained by subtracting the grain weight from the total weight of the bundle.

Yield attributing characters were recorded at the time of crop maturity. Five plants were chosen at random from each treatment to record the yield-related characteristics that were found. The CCS Haryana Agricultural University website offers OPSTAT software, which was used to analyze the data (Sheoran *et al*., 1998) [11]. Using a variety of weather parameters, such as maximum temperature (Tmax, °C), minimum temperature (Tmin, °C), morning relative humidity (RHm, %), evening relative humidity (RHe, %), maximum possible sunshine hours (hr/day), intercepted photosynthetic active radiation (iPAR), which was numerically calculated for Hisar station, and sunshine hours (SSH, Hours/day), the accumulated agro meteorological indices were calculated under twelve nutrient sources applied in wheat and pearl millet for the corresponding period. The following was computed using daily meteorological data from the CCSHAU agrometeorological observatory in Hisar.

Growing degree days/Heat Units

The calculation of growing degree days (GDD), commonly referred to as heat units (HU), began with a base temperature of 10 °C. For every phenophase, the total sum of degree days was found. Using daily meteorological data, the heat unit and heliothermal unit were calculated. The daily mean temperature above the base temperature was added up to get the accumulated heat unit (Accu. HU), which is represented in degrees Celsius each day. We computed this using the formula that follows:

$$GDD/HU = \sum \square (Tmax. + Tmin.)/2 - Tb \qquad (i)$$

Where, Tmax = Daily maximum temperature (ºC), Tmin = Daily minimum temperature (ºC)
Tb = Minimum threshold/base temperature

Heliothermalunit (HTU)

The heliothermal unit (HTU), which is measured in ºC day hour and is the product of heat unit and bright sunshine hours for a day, was calculated using the following equation to find the sums of HTU for specific phenophases of interest.

$$HTU = \square (GDD/HU x n),$$

Where, n =Actual sunshine hours…(ii)

Heat use efficiency (HUE)

The heat use efficiency (HUE) was computed in the grain yield of *Pearl millet* over the accumulated growing degree days (GDD).

Grain yield of Pearlmillet

HUE (kgha^{-1} per ºC day) = Accumulated GDD

Where, HUE = Heat use efficiency (kg ha-1 per ºC day)

GDD=Growing degree days of soybean crop

Photothermal units (PTU)

One of the fundamental elements regulating the duration of vegetative growth in photosensitive crops is day and night. Photo-thermal units, which are expressed in degrees Celsius per day, are calculated by multiplying the total value of rising degree days by the hours of maximum sunshine. In mathematics, PTU can be computed using the following formula:

$$\text{Photothermal units} = \sum (GDD \times N)$$

Where

N = Maximum possible sunshine hours

Results and Discussions

Yield attributes and yields of pearl millet

The information about pearl millet yield qualities and yields shown in Table 2 showed that different nutrient regimes had a substantial impact on the test weight and number of effective tillers/mrl of pearl millet in both experimentation years. Depending on the treatment, there were anywhere from 18 to 32 productive tillers per milliliter at harvest. The current study found that there were considerably more effective tillers/mrl in both years, with the highest number (32) in T_6 (50% recommended dose of NPK dose via T_5 (recommended NPK dose by chemical fertilizers in both kharif and rabi) is given after fertilizers + 50% N through FYM in kharif and recommended NPK dose through fertilizers in *rabi*. The 2017 pearl millet test weight (7.6) was highest in treatments T_8 and T_9, and the 2018 test weight (8.8) was highest in treatment T_6. In both of the testing years, treatment T_6 had the maximum grain production of pearl millet (3,608 kg/ha in 2017 and 3,640 kg/ha in 2018), which was much greater than that of the other treatments. Nonetheless, in 2017, the grain production in treatment T_5, which advised using a chemical fertilizer dose of NPK for both kharif and Rabi, was comparable to that of treatment T_6. This could be because fertilizer and FYM worked together to facilitate the simple release of various nutrients and the pearl millet crop's uptake of them, which improved growth and yield characteristics. These findings completely concur with those of Khambalkar *et al*. (2012) [2] and Thavaprakaash and Velayudham (2009) [12]. Information about pearl millet straw yield (Table 2) shows that higher fertilizer levels led to a noticeably higher yield of pearl millet straw. The treatment T_6 (50% recommended dose of NPK dose through fertilizers + 50% N through FYM in kharif and recommended NPK dose through fertilizers in rabi) also produced the highest straw yield of pearl millet, which was followed by treatment T_5 (recommended dose of NPK dose through chemical fertilizers both in kharif &rabi). The increased plant height, leaf area, and dry matter production may be the cause of this rise in the straw yield. Polara *et al*. (2020) [7] have also published similar results. Treatment T_1 yielded the lowest values of grain and straw (1068 and 1520 kg/ha in 2017 and 2622 and 3222 kg/ha in 2018, respectively).

Agro-meteorological indices and phenology

For the pearl millet cultivar HHB-197, accumulated agroclimatic indices, such as growing degree days, heliothermal units, and photothermal units, were calculated for various nitrogen regimes from sowing to physiological maturity stage. Similar meteorological conditions prevailed in all twelve treatments, which is represented in the similar accumulated values of GDD, PTU, and HTU (Table 1). Highest accumulated growing degree day, heliothermal unit as well as photothermal units were recorded higher in the year 2017 as compared to 2018. An attempt was also made to compute Heat use efficiency (HUE) of different nitrogen regimes for two consecutive crop seasons to compare the relative performance of different treatments with respect to utilization of heat by *pearl millet*. Heat use efficiency i.e., efficiency of utilization of heat in terms of dry matter accumulation is very important aspect, which has great practical application (Rao *et al*., 1999) [8]. The total heat energy available to any crop is never completely converted to dry matter under even the most favorable agro-climatic conditions. Efficiency of conversion of heat energy into dry matter depends mainly upon genetic factors, sowing time and type of crop. Varying nutrient regimes had significant influence on heat use efficiency of pearl millet for grain and straw during both the year of experimentation (Table 3). Heat use efficiency of pearl millet for grain varied from 0.57 to 1.96 among different treatments. Treatment T_6 being at par with treatment T_5 recorded significantly higher value of Heat use efficiency for grain during both the year of study. This increase in HUE might be due to better utilization of heat intreatmentswhereFYMwasintegratedwithfertilizers.Similarly amongdifferenttreatments heat use efficiency of pearl millet for straw was also calculated significantly higher in treatment T_5 and T_6. However, there was no significant difference appeared due to application of different nutrient sources on HUE for straw in treatment T_5 and T_6 during both the years of experimentation. The study illustrates positive impact of varying nutrient sources on HUE of pearl millet. *Pearl millet* is an indispensable cereal crop of the dry arid and semi-arid regions of India. Its dry weight increased with intercepted PAR during vegetative and much of the reproductive phase. High temperature was negatively correlated with yield at vegetative phase while it was positively correlated at grain filling phase. Days taken to 50% flowering of pearlmillet varied from 42.3 to 49 days due to varying nutrient regimes (Table 3). Number of days taken to 50 percent flowering of pearlmillet was late by 4-5 days in treatment T_5 over control during both the years of experimentation. It might be due to better vegetative growth in INM treatments and hence delay in phenological stages of crop growth. In the manurial application where green manuring or wheat straw or FYM were applied, 50 percent flowering was significantly late over control. Similar results of delay in days to 50% flowering due to higher doses of nitrogen application.

Table1: Average agrometeorological indices of *pearl millet* during experimental years

Growing degree days (0C day)		Heliothermal unit (0C day hr.)		Photothermal units (0C day hr.)	
2017	**2018**	**2017**	**2018**	**2017**	**2018**
1868	1854	12545	9876	23771	23616

Table 2: Yield attribute sand yields of *pearl millet* under varied nutrient regimes in pearl millet–wheat cropping system

Treatment			No. of effective tiller/mrl		Test weight (g)		Grain yield (kg/ha)		Straw yield (kg/ha)	
	Kharif	***Rabi***	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
T_1	Control (no fertilizer)	Control (no fertilizer)	20	18	6.8	7.0	1068	1520	2622	3222
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers	23	24	7.7	7.8	2205	2185	4616	5015
T_3	50% recommended NPK dose through fertilizers	Recommended NPK dose through fertilizers	24	24	7.2	8.0	2065	2435	4798	5530
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers	27	25	7.3	8.1	3049	3072	6533	7250
T_5	Recommended NPK dose through fertilizers	Recommended NPK dose through fertilizers	30	31	7.1	8.5	3426	3398	7356	9285
T_6	50% recommended NPK dose through fertilizers + 50% N through FYM	Recommended NPK dose through fertilizers	32	32	7.0	8.8	3608	3640	7487	9780
T_7	75% recommended NPK dose through fertilizers + 25% N through FYM	75% recommended NPK dose through fertilizers	29	30	7.2	8.5	3262	3305	6911	8750
T_8	50% recommended NPK dose through fertilizers + 50% N through wheat straw	Recommended NPK dose through fertilizers	27	28	7.6	8.2	3302	3280	6997	6025
T_9	75% recommended NPK dose through fertilizers + 25% N through wheat straw	75% recommended NPK dose through fertilizers	27	27	7.6	8.1	3237	3245	7144	7754
T_10	50% recommended NPK dose through fertilizers + 50% N through GM	Recommended NPK dose through fertilizers	30	30	7.1	8.3	3387	3352	7302	9210
T_11	75% recommended NPK dose through fertilizers + 25% N through GM	75% recommended NPK dose through fertilizers	28	28	7.2	8.2	3289	3265	7294	8620
T_12	Farmer's Practice	Farmer's Practice	23	24	7.7	8.2	2152	2652	4449	7515
CDaT$_5$%			1.31	0.98	0.33	0.28	224	196	641	853

GM: Green manure

Table 3: Heat use efficiency and days to 50% flowering of *pearl millet* as influenced by varying nutrient regimes

Treatment			Heat use efficiency (kg ha-1per °C day)				Days taken to 50%flowering (DAS)	
	Kharif	***Rabi***	**For grain**		**For Straw**			
			2017	**2018**	**2017**	**2018**	**2017**	**2018**
T_1	Control (No fertilizer)	Control (No fertilizer)	0.57	0.82	1.40	1.74	44.6	42.3
T_2	50% recommended NPK dose through fertilizers	50% recommended NPK dose through fertilizers	1.18	1.18	2.47	2.70	45.3	43.6
T_3	50% recommended NPK dose through fertilizers	Recommended NPK dose through fertilizers	1.11	1.31	2.57	2.98	45.6	43.6
T_4	75% recommended NPK dose through fertilizers	75% recommended NPK dose through fertilizers	1.63	1.66	3.50	3.91	46.3	44.3
T_5	Recommended NPK dose through fertilizers	Recommended NPK dose through fertilizers	1.83	1.83	3.94	5.01	48.8	47.0
T_6	50% recommended NPK dose through fertilizers + 50% N through FYM	Recommended NPK dose through fertilizers	1.93	1.96	4.01	5.27	49.0	47.3
T_7	75% recommended NPK dose through fertilizers + 25% N through FYM	75% recommended NPK dose through fertilizers	1.75	1.78	3.70	4.72	47.8	46.0
T_8	50% recommended NPK dose through fertilizers + 50% N through wheat straw	Recommended NPK dose through fertilizers	1.77	1.77	3.75	3.25	48.0	45.6
T_9	75% recommended NPK dose through fertilizers + 25% N through wheat straw	75% recommended NPK dose through fertilizers	1.73	1.75	3.82	4.18	47.6	45.6
T_10	50% recommended NPK dose through fertilizers + 50% N through GM	Recommended NPK dose through fertilizers	1.81	1.81	3.91	4.97	48.3	46.0
T_11	75% recommended through fertilizers + 25% N through GM	75% recommended NPK dose through fertilizers	1.76	1.76	3.91	4.65	48.0	46.6
T_12	Farmer's Practice	Farmer's Practice	1.15	1.43	2.38	4.05	47.1	45.1
CDaT$_5$%			0.09	0.08	0.07	0.08	0.4	0.3

Acknowledgement
Authors acknowledge to CCS Haryana Agricultural University, Hisar, Haryana, 125004, India for providing all the facilities for the conductance of the experiment.

Conclusion
After a two-year study, it was determined that different nutrient regimes in Haryana's semi-arid climate were the cause of the observed variability in agro-meteorological

indices such as HUE, yield characteristics, yields, and phenology of pearl millet. Higher yield characteristics, yield, and HUE of pearl millet are achieved with the application of integrated sources of nutrients. The number of days it took for pearl millet to reach 50% blooming was inversely connected with HUE.

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