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Research Article

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Effect of weather parameters on growth stages of winter maize explain the grain yield

Pramod Prasad Dahal[*1], Komal Bahadur Basnet[2], Shrawan Kumar Sah[3] and Tika Bahadur Karki[4]

Abstract

A study was conducted on research farm of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal during winter season of 2015/16 laid out in split-split plot design with three replications consisting of two FYM levels (FYM at 10 t ha^{-1} and no FYM application), three nitrogen levels (100, 75 and 50% N of recommended dose P and K remaining constant) and two levels of seed inoculation (*Azotobacter chrococcum* seed inoculation and no inoculation) with Rampur-2 maize hybrid in Nepal. One of the major factor affecting maize production is weather and this paper is prepared to assess the suitability of weather condition at different growth stages of winter season hybrid maize in condition of western Chitwan, Nepal at NMRP. The result shows that the requirement of the maize crop during different growth stages i.e. temperature, rainfall, relative humidity were fulfilled which helped to obtain remarkably higher grain yield (4.26 t ha^{-1}) in the experiment compared to average national grain yield (2.84 t ha^{-1}) of maize.

Keywords: Integrated plant nutrient management, Winter maize, Weather parameters, Maize growth stages

Contacts of authors

* **To whom correspondence should be addressed: Pramod Prasad Dahal**

[1] Agriculture Extension Officer,Governemnt of Nepal,Nepal.
[2] Agriculture and Forestry University, Agronomy, Rampur, Chitwan.
[3] Agriculture and Forestry University, Agronomy, Rampur, Chitwan.
[4] Nepal Agricultural Research Council, Singhdurbar Plaza.

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Introduction

Maize (*Zea mays* L.) can be grown easily in any season and is important cereal crop due to fast growing nature, higher yield, palatability and nutritiousness resulting easily accessible food and feed for humans as well as animals [1]. In Nepal maize is grown as a staple food crop for many years. In terms of area and production, maize ranks second to rice [2]. It shares about 6.54 % in Agricultural Gross Domestic Product (AGDP). Maize can grow in a wide range of environment; however, warm climate with temperature ranging from 21 to 30 °C is most favorable [3]. Moreover, it was reported [4]that maize growth is best with temperature between 18 °C and 27 °C during day time and around 14°C at night. The experimental site falls under the sub-tropical humid climatic belts of Nepal with three distinct seasons i.e. November to February (winter), March to May (hot spring) and June to October (rainy). The maximum temperature during the coldest month of year (December to February) reaches to 27 °C whereas the minimum temperature during this period ranges from 6 to 10 °C. Likewise, the maximum temperature during hottest month of year (May to June) is measured up to 42 °C. Recent studies conclusively proved that maize is a potential winter season crop having three times higher yield potential than kharif crop [5]. According to annual report of NMRP [6], the productivity of winter maize is about 6-7 t ha^{-1} while that of summer maize is around 4.0 t ha^{-1}.

The mean annual temperature trend at Rampur, Chitwan during 1968 to 2008 showed that the increase of temperature seemed to be more in the recent decade than the former decade and the trend was 0.039 °C per year [7]. Thus the changed weather condition can create impact upon the maize production as yield of maize is primarily influenced by sunlight, temperature, available plant nutrients and water supply [8]. One of the major factors affecting maize production is weather and this paper is prepared to assess the suitability of weather condition at different growth stages of winter season hybrid maize in condition of western Chitwan, Nepal at NMRP.

Materials and Methods

A experiment was conducted during winter season (October to March) of 2015 at the research field of National Maize Research Program (NMRP), Rampur, Chitwan, Nepal with Rampur Hybrid-2 variety. The experimental soil was sandy loam in texture, having slightly acidic pH (5.4). Organic matter (4.02), total nitrogen (0.11), available phosphorus (58.0 kg ha-1), available potassium (253.8 kg ha-1). The experiment was laid out in strip-split plot design consisting of 12 treatments with three replications. FYM levels as main plots (FYM at 10 t ha^{-1} and no FYM application), three nitrogen levels as sub plots (100, 75 and 50% N of recommended dose P and K remaining constant) and two levels of seed inoculation (Azotobacter chrococcum seed inoculation and no inoculation) as sub-sub plots. Farm Yard Manure (FYM) was applied two weeks before sowing and was incorporated into soil. Chemical fertilizers: urea, single super phosphate (SSP), diammonium phosphate (DAP) and muriate of potash (MOP) were also applied as main source of nitrogen, phosphorus and potassium, respectively. Urea was applied in three splits; at sowing, knee high and tasseling stages. Azotobacter was applied as seed inoculation preparing of slurry of 10% sugar solution mixing 100 gm of sugar on 1000 ml of water and was boiled and azotobacter were applied after cooling on shade. Harvesting was completed on March of 2014, from net plot area. Weather data were collected from meteorological data center near (100m) the research field.

Weather condition during the experimentation

The experiment field receives regular precipitation of 1919.5 mm (NMRP, 2015/16).The average weather parameters regarding minimum as well as maximum temperatures, relative humidity and total rainfall are presented at an interval of two weeks in **Figure 1**. The weather condition during the period of experimentation presented in the **Figure 1** and **Table 1** shows that the higher value of maximum temperature (33.85 °C) was recorded on 1st week of September which gradually declined up to 3rd week of December (21.1 °C). Thereafter, it increased up to 24.69 °C on 1st week of January and then declined to 21.05 °C on 4th week of January. Further, the values of maximum temperature were found to increase up to 32.84 °C on 2nd week of March and then remained at the same level at the 4th week of March (32.51°C).

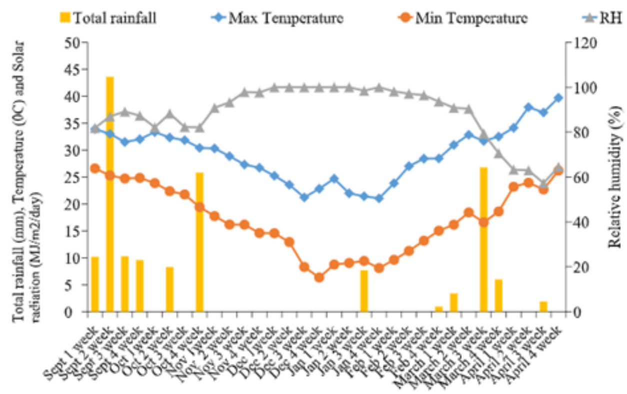

Figure 1. Weather condition during the course of experimentation at NMRP, Rampur, Chitwan, Nepal, 2015/16.

On the other hand, the minimum temperature was found to decrease from first week of September (26.60 °C) to 4th week of December (6.36 °C) and then remained almost at the same level (8.16 to 9.64 °C) from 1st week of January to 1st week of February and thereafter increased to 18.43 °C on 2nd week of March. Further, similar minimum temperature (18.61 °C) was recorded on 4th week of March. In spite of it, the maximum rainfall of 43.6mm was recorded on 2nd week of September and thereafter it declined to zero precipitation on 1st week of October. However, a remarkable rainfall of 25.83mm was recorded on 4th week of October. Further, there was no rainfall from the 1st week of November to 3rd week of February with the exception of January 3rd week where there was a rainfall of 7.7 mm. The relative humidity was found to increase from 1st week (81.86%) to 3rd week (89.14%) and then declined on 4th weeks (87.33%) of September. Similarly, it increased from 1st (82.14%) to 2nd (88.29%) and then remained at the same level in 3rd (82.29%) and 4th (82.10%) weeks of October. Further, the values of relative humidity were increasing from 90.86% on 1st week of November to 100% on 1st week of December and thereafter remained at this level up to 4th week of January with exception of 3rd week of January where it was a little decreased (98.43%). Thereafter, the

Table 1. Weekly maximum and minimum temperature, relative humidity, rainfall and solar radiation during research period at NMRP, Rampur, Chitwan, Nepal, 2015/16.

Stage	Date	Min Temp	Max. Temp	Avg	Rainfall	RH%
Germination	2nd week of Oct.	23.125	32.845	27.99	8.3mm	85.21
Knee high	1st week of Nov.	17.75	30.31	24.03	0	90.86
Grand Growth	1st-4th week of Nov.	16.18	28.305	22.24	0	94.92
Tasseling and Silking	1st-2nd Dec.	13.75	24.39	19.07	0	100
Milking	4th of January	8.11	21.05	14.58	0	100
Dough	4th of Feb	15.04	28.45	21.75	0.96 mm	95.03
Grain Filling	3rd Jan-3rd Feb	10.33	24.35	17.34	7.7mm	93.615
Physiological Maturity	3rd March week	16.59	31.69	24.14	26.8mm	79.43
Total rainfall during crop season		14.35	27.23	20.79	72.99mm	93.86

relative humidity gradually declined from 98.14% on 1st week of February to 70.60% on 4th week of March.

Statistical Analysis

Analysis of variance (ANOVA) was used to test the row, column and interaction effect of FYM, nitrogen levels and biofertilizer on yield and yield attributing characters of maize at 5% level of significance. Values were computed using software program MSTATC, Gen STAT and Microsoft excel 2010.

Results

Analyzed data of phenological stages (**Table 2**) showed that on an average, the emergence of maize seeds occurred at 6.36 DAS whereas the maize plants attained knee high stage (34.06 DAS) after around one month of seed emergence Further, tasseling stage (73.10 DAS) was recorded after one month of the knee high stage. There was only four days difference between tasseling and silking stages. The silking, milking and dough stages were observed at 76.94, 126.18 and 144.17 DAS, respectively. Finally, the maize crop was physiologically matured after about 20 days of dough stage (164.53 DAS).

Discussion

The average minimum and maximum temperature during the cropping period were 14.35 and 27.23 °C suitable for growth and development of maize, respectively (**Table 1**). Further, the annual precipitation of experimental area was 1919.5 mm (NMRP, 2015/15), however, maize requires rainfall of about 600 - 1,200 mm throughout the year with uniform distribution [15]. Thus, the availability of water was sufficient for growth and development of the maize crop.

The minimum temperature required for maize seed germination is 10 °C. In addition, emergence gets far more rapid and uniform above 16 °C and around the temperature of about 20 °C, maize usually emerges within 5-6 days after sowing [9]. Thus, the minimum and maximum temperatures recorded during the germination of maize seed in the experimental site were 23.13 °C and 32.84 °C with the average of 27.99 °C. Therefore, the germination of seeds took place within 6 days. [10] stated that for uniformity of initial stand, a minimum temperature of 17 °C to 20 °C is required but during knee high stage, the average temperature was 24.03 °C with minimum and maximum temperatures of 17.75 and 30.31 °C, respectively. This indicates that average temperature was suitable for the establishment of plant stand in the experiment. Further, during vegetative growth stage (grand growth stage) the minimum, maximum and average temperatures were 16.18, 28.31 and 22.24 °C, respectively. In this context, Joshi [11] reported that optimum temperature for vegetative phase ranges from 28 to 34 °C. Venkataraman and Krishanan [4] also mentioned that range of temperature for the growth of maize is from 9°to 46 °C with the optimum around 34 °C during vegetative growth stage.

Thus, the minimum temperature was found higher but maximum temperature was slightly lower due to winter season. However, it was close to the temperature given by Joshi [11]. Moreover, in the experimental site, the average temperature during tasseling and silking stages equaled to 19.07 °C. With respect to it, Venkataraman [12] reported that the optimum temperature for tasseling ranges from 21 to 30 °C and temperatures above 32 °C during reproductive stage reduced the yield. Thus average temperatures during tasseling and silking were close to optimum level.

Further, minimum and maximum temperatures during these stages were 13.75 and 24.39 °C, respectively. In respect of it, Berbecel and Eftimescu [13], mentioned that the maximum temperature above 32 °C around tasseling and pollination increases the differentiation process of the reproductive parts and conse-

Table 2. Weekly maximum and minimum temperature, relative humidity, rainfall and solar radiation during research period at NMRP, Rampur, Chitwan, Nepal, 2015/16. Table shows Treatments (Tr), Germination (Gr), Knee high (KH), Tasseling (Tas),Silking(Si), Milking (Mi), Dough (Do), Physiological maturity (PM), and Grain Yield (t ha^{-1}) (GY)

Paramter	Phenological stages (DAS)								
	Tr	Gr	KH	Tas	Si	Mi	Do	PM	GY
FYM levels (t ha^{-1})									
	0	6.56	34.56	74.21	77.39	126.33	145.06	164.4	3.91
	10	6.17	33.56	73.35	76.5	125.61	145.28	164.61	4.58
	Statistical analysis								
	F test	NS	NS	NS	NS	NS	NS	NS	NS
	LSD (=0.05)	1.04	1.9	2.89	2.43	3	1.57	2.91	2.2
	SEm (±)	0.17	0.31	0.48	0.4	0.5	0.26	0.82	0.36
Nitrogen levels	Tr	Gr	KH	Tas	Si	Mi	Do	PM	GY
	50	6.41a	35.67a	74.50a	78.92a	126.08a	146.17a	166.58a	2.95c
	75	6.42a	34.92a	72.00b	75.67b	126.42a	145.16a	165.42a	4.64b
	100	6.25a	31.58b	72.08b	75.24b	125.41a	144.17b	162.58b	5.16a
	Statistical analysis								
	F test	NS	*	*	*	NS	NS	*	**
	LSD (=0.05)	0.42	2.83	1.72	2.57	1.67	1.76	2.23	0.41
	SEm (±)	0.13	0.87	0.53	0.79	0.51	0.54	0.68	0.12
Biofertilizer	Tr	Gr	KH	Tas	Si	Mi	Do	PM	GY
	No inoculation	6.33	34.17	73.11	77.28	126.54	145.28	164.72	3.95
	With inoculation	6.39	33.94	72.61	76.61	125.89	145.06	164.33	4.55
	Statistical analysis								
	F test	NS	NS	NS	NS	*	NS	NS	**
	LSD (=0.05)	0.21	1.01	0.67	0.72	0.48	1.1	0.5	0.4
	SEm(±)	0.07	0.35	0.22	0.23	0.17	0.35	0.162	0.13
	CV, %	4.5	2.1	1.5	1.3	1	0.5	0.6	12.9
	Grand mean	6.36	34.06	72.88	76.94	126.18	144.17	164.53	4.25

Recommended dose of Nitrogen: 120 kg N ha^{-1} Azotobacter chroococcum seed inoculation: 40 g kg^{-1} seed

quently the rate of kernel abortion. Further, according to Adjetey [3] at high temperatures the pollens gets shed before silk become receptive or cause either death of tassel or drying out of silk. Therefore, to achieve higher grain yield the temperatures of the late vegetative and reproductive phases should be relatively lower than 30 °C which was also recorded in this experiment.

Finally, during maturity, the minimum, maximum and average temperatures were 16.59, 31.69 and 26.8 °C respectively. Joshi (2015) stated that optimum temperature during ripening stage ranges from 32 to 35 °C. Thus, the maximum temperature of the experimental site was close to it but the average temperature was a little lower which might be related to the winter season and subtropical climatic condition.

Thus, on the basis of above discussion it is obvious that in general, the weather condition related to temperature was suitable for growth and development of maize. Further, a rainfall of 43.60, 10.3 and 9.6 mm were recorded at three, two and one week before germination, respectively (**Figure 1**) which provided enough moisture for germination of maize seeds. Moreover, a rainfall of 8.3mm was recorded at sowing which also helped in better germination of seeds. Germination of maize seed was completed within 6 days.

No rainfall was recorded during knee high and grand growth stages. Others [10] stated that moisture stress in early growing season causes a large reduction in grain yield. Therefore, the experimental plots were irrigated at this stage. Kranz*et al.,* [14] mentioned that corn requires most of the water during the early reproductive growth stages i.e. tasseling and silking.

Moreover, the requirement of maize in water is more prominent during the tasselling to silking stage [15] which is considered critical as grain formation initiates during this period. Thus the availability of soil moisture at the time of tasselling is therefore vital for the production of high yield in maize [16].

Futher, period of silking and ear growth the corn is most sensitive to moisture deficiency as far as the grain yield is concerned [4]. However, there was no rainfall during this period in the experimental site due to which the crop was irrigated at this phase.

Another critical period with respect to crop requirement in moisture is grain filling period. Corn requires one third part of seasonal water requirement at beginning of dough stage. Drought or water stress at dough stage results in acceleration of maturity preventing grains from gaining full size as well as weight [14]. However, there was 7.7 mm rainfall during grain filling period and 0.96mm at dough stage which might had helped to some extent fulfill the crop requirement in water.

Thus, in general, the requirement of the maize crop in water was fulfilled either through rainfall or irrigation which helped to obtain remarkably higher average grain yield (4.26 t ha^{-1}) in the experiment as compared to average national grain yield (3.09 t ha^{-1}) of maize (MOAD-ABPSD, 2015). It concludes from above discussion that weather recorded during different key growth stages of winter maize in the experimental site were resultant and it is essential to give emphasis on weather conditions in improvement of grain yield of winter maize.

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