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Effect of Sowing Dates and Maize Cultivars in Growth and Yield of Maize along with their Agro-Climatic Indices in Nawalparasi, Nepal

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ABSTRACT

A field experiment on different maize cultivars planted at different sowing dates were accomplished at Kawasoti-5, Nawalparasi during spring season of 2013 to find suitable sowing date and maize cultivar for the location. Along with this, effect of sowing dates and maize cultivars on different agro-climatic indices were also calculated using formulas. Result showed that RML-4/RML-17 produced higher kernel rows ear^{-1} (13.77), kernel per row (30.42) and test weight (244.9 g). Significantly higher grain yield was also found for RML-4/RML-17 (6.03 tha^{-1}) compared to Poshilo makai-1 (4.73 t ha^{-1}), Arun-2 (3.55 t ha^{-1}) and Local (2.92 t ha^{-1}). Earlier sowing date (7th April) produced higher kernel row^{-1} (27.97), kernel rows ear^{-1} (12.89) and 1000 grain weight (230 g). Significantly higher grain yield (5.13t ha^{-1}) was obtained in earlier sowing date (7th April). Although the mean ambient temperature during research period was increasing with delayed sowing, days to attain different phenological stages decreased with late sowing. The statistically similar GDD was recorded for different sowing dates and higher PTI values were noticed with delay in planting. Similarly, heat use efficiency (HUE) was found higher in early sowing date. Arun-2 had small reduction in HUE so, it can be considered stable and best cultivar among the tested cultivars.

Keywords: Spring maize, Sowing dates, Cultivars, Grain yield, GDD, HUE, Phenological stages

INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crops both in term of area and production after rice in Nepal. It has the highest yield potential over other cereals and thus known as 'the queen of cereals' (Singh, 2002). It is grown in about 906253 ha land with 206772 metric tons total production and 2.33 mt ha^{-1} productivity (Agricultural Diary, 2069). Maize contributes 9.5% AGDP and 3.15% GDP (MoAD, 2012). Maize occupies about 28.32% of the total agricultural land cultivated, and shares about 23.89% of the total cereal production in Nepal (MoAC, 2009/10). The overall demand for maize will be increased by 6-8% per annum largely for the next two decades as a result of increased demand for food in hills and feeds in terai and inner terai and, this increased demand could only be met by increasing the productivity of maize per unit area of land (NMRP, 2009).

Rainfed farming means the cultivation of crops on relatively dry land that lacks easy access to irrigation and moisture requirement at any growth and development stages of crop. Rainfed farming areas fall mainly in arid, semi arid and dry sub-humid zones in the world but the Nepalese sub-tropical region is also rainfed. In Nepal, about 65% of the total arable land is under rainfed (Thapa, 1995). The variation in rainfall under rainfed zone especially during spring season feels long dry spell, early withdrawal and also increasing temperature caused stressful environment to plant growth, all of which strongly influence the productivity level of maize.

Optimum planting date is a cost-less tool to improve the yield of maize. Spring maize is normally planted in mid of February. Maize planted in earlier spring season is facilitated by favorable temperature, availability of reserved soil moisture of long winter for vegetative growth, but drought problem during reproductive period creates stressful environment to the crop. When maize planting date is shifted to late spring, higher temperature stress during major crop period will hinder plant growth and development. However, there will be plenty of soil moisture during reproductive stage due to monsoon rainfall which also could not be favorable to C_4 maize. Even though, rainfall will be adequate in post flowering period but excessive high temperature decreases crop yield by shortening of growth period and other physiological factors associated with poor grain filling. That is why, optimum sowing date for healthy crop growth is an important task to tackle changing climate during spring season.

The development of improved germplasm to meet the needs of future generations in light of climate change and population growth is of the upmost importance (Easterling *et al.*, 2007). Drought condition that often occurs in rainfed lower ecosystem seriously affects the growth and yield of maize. Most of the varieties released by National Agriculture Research Council are susceptible to drought. Even heat stress during summer season decreases crop yield with higher magnitude. To avoid high temperature and drought during post anthesis period, farmers like to cultivate short durational varieties. Farmer expects short durational variety to escape drought period and provide higher yield and net returns. However, they are still in dilemma, which varieties will provide greater yield under prevailing environment. So this

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research also focused on selection of proper variety for the particular location. Four varieties were chosen to determine the best one through research. Out of four varieties, Arun-2 and Local are short durational varieties. The major agro-climatic indices like temperature and solar radiation significantly affects the crop growth and development. The quantification of temperature and their application in predicting crop yield is a modern application in agricultural field. Environmental impact on agro-climatic indices such as heat use efficiencies and phenothermal index were studied to find there significant role in varietal selection. During both the winter and spring planting, 'Arun-2' has given more stable yield and heat use efficiency for the early and late (September 1 to November 1, and February 24 to March 4) plantings (Amgain, 2011). Remaining Poshilo Makai-1 and RML-4/RML-17 are long durational but drought tolerant varieties. From several researches, it has also been reported that hybrids can give 20-50% more grain yield than the inbred variety (Gupta *et al.,* 2010). However, the hybrid and improved cultivars of any crops are more sensitive to the environment of climatic variability than the local genotypes, and yield reduction is more on them (Amgain, 2011, Lamsal and Amgain, 2010, Bhusal *et al.,* 2009).

MATERIALS AND METHODS

Field experimentation

The field experiment was conducted at Kawasoti-5, Nawalparasi district on maize (Zea mays L.) during late spring (April to August) season, 2013. The area is located at 27^{0}66' N latitude and 84^{0}13'E longitude with an elevation of 220 M above mean sea level. The place is situated in humid sub tropical climate but resembles the foot hill and inner terai climate. During the cropping period, maximum temperature was recorded in May (Monthly average= 34.12 ^{0}C). After rainfall started from May, maximum temperature decreased slightly; however, minimum temperature was found increasing consistently and dropped slightly after July only. The highest minimum temperature was recorded during July (monthly average= 26.05 ^{0}C). Total rainfall received during research period (7th April to 27th August) was 2789.1 mm. The experiment was carried out in two factorial randomized complete block design with three replications. The treatment consists of combination of four maize cultivars (Local, Poshilo makai-1, RML-4/RML-17 and Arun-2) and three sowing dates (7th April, 22nd April and 7th May). The soil of the research site was silt loam and slightly acidic to basic in soil reaction (pH 6.2-7.4). The recommended agronomic management practices were followed to accomplish the experimentation except the fertilizer treatments. Yield and yield attributing characters were recorded, tabulated and analyzed using MSTAT-C computer software and statistical package as mentioned by Gometz and Gometz (1984).

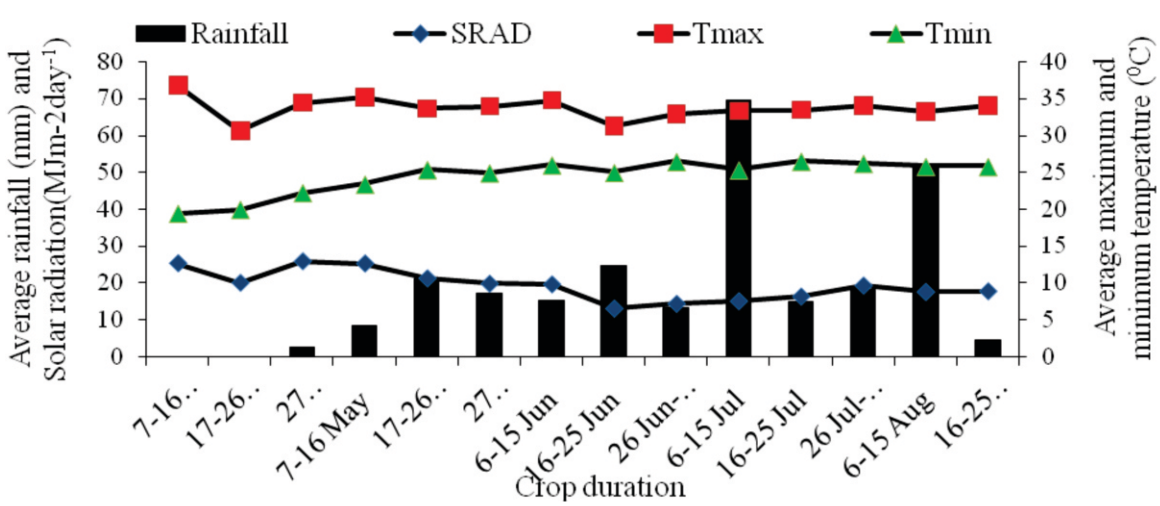

Fig. 1: Average weather records during research period (10 days interval) at kawasoti-5, Nawalparasi, 2013 (Department of Hydrology and meteorology).

The various measurements of accumulated heat units were calculated according to the following formulae of Rajput (1980).

a) Growing degree days: {(Tmax-Tmin)/2}-Tb
   Where: Tb =Base temperature= 10^{o}C
b) Phenothermal index (PTI) = GDD/Growth duration
c) Heat use efficiency = Grain yield (kg/ha)/ GDD

RESULTS AND DISCUSSION

Results summarized in Table 1 clearly indicated that number of ears ha^{-1} is insignificant for all sowing dates and maize cultivars. Kernel row ear^{-1}(12.89) and kernels row^{-1} (24.47) in 7th April planted maize were recorded highest followed by 22nd April and 7th April planted maize cultivars. It might be due to favorable temperature in early sown maize cultivars. A number of factors could be responsible for reduction in number of kernels per row under heat stress, such as reduced pollen viability and receptivity of silk, increased frequency of kernel abortion, decreased cell division in endosperm, reduced silk capacity of developing kernels, reduced starch grain number and overall starch synthesis, increased soluble sugar accumulation, duration of grain filling, kernel development and enzyme activities (Duke and Doehlert, 1996). In case of cultivars, RML-4/RML-17 had highest kernel row ear^{-1} (13.77) and kernels row^{-1} (30.42) than other cultivars. The reason for best performance for most of the traits for hybrid might be due to added traits called heterosis. It is observed that 1000 grain weight were higher and statistically similar between maize planted in 7th April (232.0) and 22nd April (231.3) than 7th May (224.3). Suwa *et al.* (2010) reported depression in source-sink activity under high temperatures. Heat stress decreased seed filling duration (Hellewell *et al.,* 1996; Prasad *et al.,* 2006) due to which test weight of 7th May sown cultivars were found less. Similarly, test weight of RML-4/RML-17 (244.9) and Poshilo makai-1 (241.2) were found higher as these cultivars were long durational and had longer seed fill durations than short durational cultivars i.e, Local and Arun-2.

Similarly, grain yield was found higher in 7th April (5.126 tha^{-1}) followed by 22nd April (4.104 t ha^{-1}) and those planted in 7th May (3.692 tha^{-1}) had least grain yield. High night temperatures result in loss of more sugars for respiration and reduce the availability for kernel filling, thereby lowering potential grain yield (Thomison, 2010).In case of maize cultivars, RML-4/RML-17 had highest grain yield as hybrid possess hybrid vigor. It had longer crop duration, high seed fill duration, long leaf stay green character, higher leaf area index etc. Unlike grain yield, 22nd April (14.26 tha^{-1}) and 7th April (14.35 t ha^{-1}) sowing dates had higher stover yields. But, here also hybrid RML-4/RML-17 (17.18 t ha^{-1}) had highest stover yield than other cultivars.

While in case of harvest index, 7th April (0.347) planted maize cultivars had highest harvest index but remaining both sowing dates had similar and least harvest index. This finding was in agreement with Jasemi *et al.* (2013) who found harvest index was higher for plant sown on 22nd May than 13th July. But, in case of maize cultivars, both long durational cultivars had higher harvest index than short durational cultivar. It was due to longer seed fill duration, higher leaf area index, higher leaf area duration.

Table 1: Effect of sowing dates and varieties on yield attributing characters of maize during spring, 2013 at Kawasoti-5, Nawalparasi

Factors	Number of ears ha^{-1}	Kernel rows ear^{-1}	Kernels row^{-1}	1000 grain weight (g)	Grain yield at 15% MC (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Sowing dates							
7th April	59070	12.89^{a}	27.97^{a}	232.0^{a}	5.126^{a}	14.35^{a}	0.347^{a}
22nd April	57590	12.47^{b}	24.47^{b}	231.3^{a}	4.104^{b}	14.26^{a}	0.289^{b}
7th May	58150	12.22^{c}	22.73^{c}	224.3^{b}	3.692^{c}	12.58^{b}	0.290^{b}
SEm$\pm$	800.7	0.075	0.301	1.686	0.078	0.289	0.009
$LSD_{0.05}$	NS	0.219	0.883	4.946	0.227	0.849	0.027
Varieties							
Local Variety	59750	11.31^{d}	21.10^{d}	204.4^{c}	2.920^{d}	10.64^{d}	0.278^{b}
Poshilo makai-1	56540	13.17^{b}	26.13^{b}	241.2^{a}	4.725^{b}	14.47^{b}	0.326^{a}
RML-4/RML-17	58270	13.77^{a}	30.42^{a}	244.9^{a}	6.030^{a}	17.18^{a}	0.351^{a}
Arun-2	58520	11.86^{c}	22.58^{c}	226.3^{b}	3.554^{c}	12.62^{c}	0.282^{b}
SEm $\pm$	980.7	0.092	0.369	2.065	0.089	0.334	0.011
$LSD_{0.05}$	NS	0.268	1.082	6.058	0.262	0.980	0.033
CV%	4.76%	2.07%	4.16%	2.55%	6.23%	7.30%	9.15%

Means followed by common letter (s) within each column are statistically similar at LSD 0.05

Days to different phenological stages

Data collected on days to different phenological stages for different sowing dates indicated significant difference ($P<0.05$). 7th April showed higher days to knee height stage (31.42), anthesis (53.75), silking (58.08) and seed fill duration (51.25) than other sowing dates. The reason for its higher days to different phonological stages were due to relatively cooler temperature. Both developmental rate of individual organs such as leaves and the progress of the entire plant through various ontogenetic stages were quantitatively dependent on temperatures (Sinclair, 1994). Therefore, higher temperature had accelerated development rate in 7th April and 22nd May planted cultivars. While in case of varieties, Poshilo makai-1 took longer days to knee height stage (31.00), anthesis (60.33), silking (64.00) but for seed fill duration RML-4/RML-17 (60.67) to longer days than other cultivars. Poshilo makai-1 and RML-4/RML-17 were long durational cultivars so these cultivars had higher days to different phonological stages (Table 2).

Table 2: Effect of sowing dates and varieties on days to phenological stages of maize during spring season, 2013 at Kawasoti-5, Nawalparasi

Factors	Days to phenological stages (DAS)			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	31.42[a]	53.75[a]	58.08[a]	51.25[a]
22nd April	28.08[b]	52.42[b]	56.25[b]	50.83[ab]
7th May	28.00[b]	52.00[b]	55.75[b]	49.92[b]
SEm±	0.439	0.431	0.459	0.423
$LSD_{0.05}$	1.287	1.263	1.346	1.240
Varieties				
Local Variety	28.33[b]	48.33[c]	52.44[c]	44.67[c]
Poshilo makai-1	31.00[a]	60.33[a]	64.00[a]	53.67[b]
RML-4/RML-17	29.00[b]	54.00[b]	57.78[b]	60.67[a]
Arun-2	28.33[b]	48.22[c]	52.56[c]	43.67[c]
SEm±	0.538	0.527	0.562	0.518
$LSD_{0.05}$	1.576	1.547	1.649	1.518
CV%	5.21%	2.83%	2.80%	2.89%

Mean followed by common letter (s) within each column are significantly similar.

Growing degree days (GDD)

Sowing date exhibited significant different ($p<0.05$) on GDD accumulation at knee height, anthesis stages (Table 3). Growth degree days to knee height stage was higher for those cultivars which were sown in 7th April (545.4) and 7th May (540.3). It was because for 7th April planted maize had longer days to knee height stage while 7th May planted maize had higher daily average temperature. In case of anthesis, 7th May planted maize had higher growth degree days than other cultivars because of higher daily average temperature. Similarly maize cultivars also had significant different ($p<0.05$) in growth degree days. Poshilo makai-1 had higher growth degree days at knee height stage (569.5), anthesis (1138) and silking (1210) but at seed fill duration RML-4/RML-17 had higher growth degree days (1190) than other cultivars.

Table 3: Effect of sowing dates and varieties on growing degree days accumulated at different phenological stages of maize during spring season, 2013 at Kawasoti-5, Nawalparasi

Factors	Growing degree days, °C day			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	545.4[a]	976.3[b]	1062	998.8
22nd April	514.4[b]	989.1[ab]	1066	991.1
7th May	540.3[a]	1007[a]	1072	985.5
SEm±	8.677	8.592	8.227	8.401
$LSD_{0.05}$	25.45	25.20	NS	NS
Varieties				
Local Variety	517.3[b]	905.4[c]	987.1[c]	870.8[c]
Poshilo makai-1	569.5[a]	1138[a]	1210[a]	1054[b]
RML-4/RML-17	530.3[b]	1016[b]	1081[b]	1190[a]
Arun-2	516.5[b]	903.4[c]	989.0[c]	851.7[c]
SEm±	10.63	10.52	10.08	10.29
$LSD_{0.05}$	31.17	30.86	29.55	30.18
CV%	5.64%	3.00%	2.67%	2.93%

Mean followed by common letter (s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant.

Phenothermal index (PTI)

Datas collected on phenothermal index for different sowings dates indicated significant different ($p<0.05$) at all four phonological stages (Table 4). 7th May planted maize had higher phonological index at knee height stage (19.29), anthesis (19.36), silking (19.24) and seed fill duration (19.74) than other sowing dates. It's because, 7th May plantation had higher average daily temperature and short days to different phonological stages. This finding is similar to Navaprakaash *et al.* 2007, who reported pheno-phases were attained earlier in summer season and also relatively higher GDD values within short period influenced higher PTI values. While in case of cultivars, Poshilo makai-1 and RML-4/RML-17 had mutually higher phenothermal index at knee height stage, anthesis and seed fill duration than other cultivars. This happened because these cultivars consumed relatively higher growth degree days at different phonological stages.

Table 4: Effect of sowing dates and varieties on phenothermal index at different phenological stages of maize during spring season, 2013 at Kawasoti-5 Nawalparasi

Factors	Phenothermal index			
	Knee height stage	Anthesis	Silking	Seed fill duration
Sowing dates				
7th April	17.35^c	18.15^c	18.27^c	19.48^b
22nd April	18.31^b	18.86^b	18.96^b	19.49^b
7th May	19.29^a	19.36^a	19.24^a	19.74^a
SEm$\pm$	0.022	0.013	0.066	0.009
$LSD_{0.05}$	0.066	0.038	0.195	0.027
Varieties				
Local Variety	18.26^b	18.74^b	18.83	19.50^b
Poshilo makai-1	18.40^a	18.87^a	18.90	19.64 ^{a}
RML-4/RML-17	18.35^a	18.83^a	18.73	19.62^a
Arun-2	18.26^b	18.74^b	18.83	19.51^b
SEm$\pm$	0.027	0.016	0.081	0.011
$LSD_{0.05}$	0.080	0.046	NS	0.033
CV%	0.44%	0.23%	1.22%	0.16%

Mean followed by common letter (s) within each column are not significantly different ($p<0.05$) by DMRT; NS= non-significant.

Heat use efficiency of maize

It was observed that all the cultivars were more heat use efficient at early planting condition than the late growing condition (Table 5). RML-4/RML-17 had markedly higher HUE (3.502) followed by Poshilo makai-1 (2.757), Arun-2 (2.190) and the lowest with Local cultivar (1.777) under 7th April planting condition. Under late planting condtions, all maize cultivars had reduced HUE at various magnitude in comparison to early planting condition by following same trend with little bit different between Arun-2 and Poshilo makai-1. At later planting dates, Arun-2 was second heat use efficient cultivar followed by Poshilo makai. The reductions in HUE for long durational maize cultivars were higher for 7th April vs 22nd April planting and for short durational cultivars HUE reduction was higher for 22nd April vs 7th May. The decrease in HUE due to late sowing depended on varieties and found to be higher in Poshilo makai-1 (36.742%) in between 7th April vs 7th May planting followed by RML-4/RML-17 (31.296%) between 7th April vs 22nd April and Local cultivar (19.457%) between 22nd April vs 7th May planting.Arun-2 had less reduction in HUE amongst the planting time and therefore it can be concluded that it is the best cultivar for both early and late spring planting. The results are in accordance with spring and winter maize as noted by Amgain (2011).

Table 5: Heat use efficiency (HUE) of different maize cultivars as affected by planting dates

Cultivars	Heat use efficiency (HUE)			Reduction (%) due to late sowing		
	April 7	April 22	May 7	April 7 vs April 22	April 22 vs May 7	April 7 vs May 7
Local Variety	1.777	1.729	1.478	2.701	19.457	16.826
Poshilo makai-1	2.757	2.032	1.744	26.297	14.173	36.742
RML-4/RML-17	3.502	2.406	2.36	31.296	1.912	32.609
Arun-2	2.190	2.147	1.803	1.963	16.022	17.671

CONCLUSION

Rainfed maize cultivation in late spring season is very risky. However, maize planted on 7th April had higher growth rate, higher yield and its attributing characters as it was facilitated by relatively favorable temperature. Among the cultivars, Hybrid (RML-4/RML-17) was noted best as it had higher grain and Stover yield. Due to increasing temperature beyond optimum level, yield of maize cultivars planted in 22nd April and 7th May decreased by 20.015% and 27.975% respectively than planted in 7th April. Due to growing temperature, lately planted cultivars had days to different phenological stages. But, due to higher growing degree days and relatively shorter days to different phenological stages, higher phenothermal index where found in late sowing dates. Arun-2 had less reduction in HUE amongst the planting time and therefore it can be concluded that it is the best cultivar for both early and late spring planting.

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