Research Article

NITROGEN LEVELS INFLUENCE BARRENNESS AND STERILITY OF MAIZE VARIETIES UNDER DIFFERENT ESTABLISHMENT METHODS DURING HOT SPRING IN WESTERN TERAI OF NEPAL

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ABSTRACT

The national average yield of maize is less than its potential yield in Nepal mainly due to poor agronomic management and adverse climatic conditions. The effect of no-tillage combined with retention of previous crop residues and varying nitrogen fertilizer levels on barrenness, sterility, and yield of open pollinated (OP), and hybrid maize varieties were analyzed in the Western Terai region of Nepal during 2011 and 2012. The treatments included factorial combinations of two establishment methods, (a) conservation agriculture (CA; i.e., no-till with crop residue retention from previous crops) and (b) conventional practice (i.e., conventional tillage without residue retention); two varieties (OP 'Rampur Composite' and hybrid 'Rajkumar); and four N fertilizer levels [(0, 60, 120 and 180 kg ha^{-1} (during 2011), and 0, 80, 160 and 240 kg ha^{-1} (during 2012)] arranged in strip plot design to grow maize under rice-mustard-maize cropping system with three replications. Data on sterility, barrenness and yield were analyzed by using R Studio. The effect of barrenness and sterility on the grain yield was negative and significant during both the years. Both barrenness and sterility were higher (by 58.28 and 12.35%, respectively) in 2012 as compared to the 2011, also due to higher temperature and low rainfall. Higher nitrogen uptake under CA resulted the lower barrenness and sterility percentage, and hence the higher grains yield (9%). Barrenness did not effect by varieties ($p>0.05$), but the sterility ($p<0.05$) during 2012 whereas hybrid Rajkumar variety had significantly ($p<0.05$) lower sterility percent than OP Rampur Composite, resulting higher grains yield. The nitrogen uptake was significant and negatively correlated with sterility percentage. Both barrenness and sterility significantly decreased linearly with increasing the nitrogen levels while barrenness was drastically reduced as compared to the sterility. Hybrid Rajkumar had higher nitrogen uptake than OP Rampur Composite resulting lower sterility even under the nitrogen omission. Hybrid Rajkumar was more stable than OP Rampur Composite with low nitrogen application, high temperature and drought resulting- lower barrenness, sterility, and thus the high grain yield.

Key words: Conservation agriculture, barrenness, sterility, nitrogen levels

INTRODUCTION

Maize (*Zea mays* L.) is the second most important crop of Nepal after rice in terms of both area cultivation and production. The national average yield of maize (2.35 t ha^{-1}) (MOF, 2017) is far below than the attainable yield of >8.0 t ha^{-1} (Devkota et al., 2016), indicating the huge yield gaps in all the crops. Current maize production of 1.3 million t is not sufficient to meet the national demand thus yields of maize must be increased by 57% (CBS, 2014; KC et al., MOF, 2017; TrendEconomy, 2020). As the possibility of expanding area under crops in future is very limited, the required extra production has to come through increase in productivity. Poor crop management practices, low soil fertility, extreme climatic conduction induces the physiological abnormalities of maize, both the bareness and sterility, resulted in poor yield (Raza et al., 2019; Sangoi, 2001).

One of the major factors that determines the effective plant stand of maize is barrenness, the failure of a plant to produce a normal ear (Boomsma et al., 2009). The sterility is due to lack of fertilization of the female florets. In addition to high plant densities (Sher et al., 2017), barrenness may also be caused by moisture and mineral deficiencies even at low plant populations (Aslam et al., 2013). Grain yield may be markedly reduced by barrenness when open pollinated varieties and hybrids are grown with increased plant population. When there is increasing practice of maintaining higher plant populations, it is desirable to understand the factors affecting barrenness. The male inflorescence (i.e. tassel), which is derived from the shoot apical meristem, is differentiated first and has developmental priority over the female flower (i.e. ears), located at the tip of axiliary branches (Sangoi, 2001). The degree of competition between tassel and ear development is highly related to the plant's environment. Under favorable conditions (water, light and nutrients) there is less competition between the male and female inflorescences while under less favorable conditions, particularly in dense plantings (Sangoi et al., 2002), low soil nutrient status (Subedi et al., 2006) or with drought stress, apical dominance is increased and ear development decreased. The net result of this pattern of development is an increase in barrenness and a decrease in grain yield. Cob formation and the number of kernel rows per cob are already formed in the knee high stage. The number of kernels per kernel row is fixed approximately after one to two weeks before flowering. Under severe drought stress before flowering, the female flowers are delayed and the time from end of tasseling to the appearance of the silks increases. Incomplete ear fill may also be related to kernel abortion, i.e. partial sterility. Partial sterility is mainly due to the deficiency of assimilates after pollination due to shortage of radiation (Hayashi et al., 2015), water deficiency during silking period (Sangoi & Salvador, 1998), decreased pollen viability due to high temperatures during pollination (Hatfield & Prueger, 2015), and elongation of the anthesis - silking interval (Chen et al., 2015). If photosynthetes is limited during the early stages of kernel development, then kernels at the tip of the ear may abort. Kernels at the tip of the ear are the last to be pollinated and cannot compete as effectively for nutrients as kernels formed earlier. Heat and drought (as well as other stress conditions, such as nitrogen deficiency, hail, and foliar disease damage) may cause a shortage of nutrients that lead to kernel abortion, resulted in the sterility.

Genotype, agronomic practice and the combination of genotype and agronomic practice affect yield performance. Incidence of barrenness and sterility is affected by genotypes, and interaction of genotypes and nitrogen levels (Subedi et al., 2006), as well as due to the interaction of tillage, genotypes and nitrogen levels (Olness et al., 1990) . Thus this research was done with the objective to analyze the effects of tillage management, genotypes and nitrogen levels to the physiological aspects of yield attributes, i.e., barrenness and sterility of maize during hot spring of 2011 and 2012 in western terai of Nepal.

MATERIAL AND METHODS

Site description

The experiment was done in three farmers' field in the Sunawal village, Nawalparasi district, Western Terai region of Nepal (27°36'N and 83°38'E and 131 masl) during 2011-2012 and 2012-2013. The experimental fields had physical soil properties ranging from sandy loam to clay/clay loam with almost neutral pH. The total soil N ranged from low to medium; while organic carbon (OC) and available potassium were low and available phosphorus was medium (Table 1).

Table 1. Initial physical and chemical soil properties of the experimental fields at Sunawal, Nawalparasi, Nepal, 2011

Soil properties	Soil depth			Analysis methods
	0-10 cm	10-20 cm	20-30 cm	
Soil pH	7.15	7.20	6.90	Beckman electrode pH meter (Cottenie et al., 1982)
Organic C (%)	1.17±0.03	1.14±0.01	1.05±0.02	Walkey and Black (Estefan et al., 2013)
Total N (%)	0.097±0.003	0.103±0.003	0.093±0.003	Kjeldahl distillation (Bremner & Mulvaney, 1983)
Available P (kg ha^{-1})	31.00±0.58	35.33±3.93	33.33±2.19	Modified Olsen's (Olsen et al., 1954)
Available K (kg ha^{-1})	97.00±0.58	113.67±7.51	105.67±4.63	Ammonium acetate extraction method (Pratt, 1965) using flame photometry
Soil texture	Loam			
Sand (%)	50.33±6.69			Hydrometer method (Gee & Bauder, 1986)
Silt (%)	29.33±5.33			
Clay (%)	20.33±2.73			

The experimental site lies in the subtropical humid climate belt of Nepal. The area has sub-humid type of weather condition with cool winter, hot summer, and distinct rainy season with annual rainfall of about 1800 mm. It is characterized by three distinct seasons: rainy season (June to October), cool winter (November to February), and hot spring (March to May).

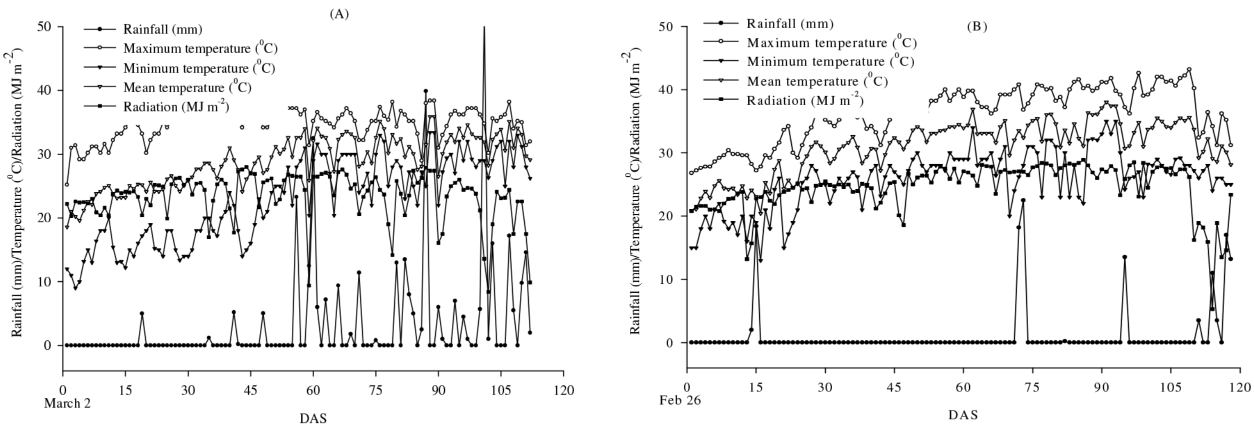

Figure 1. Minimum and maximum monthly temperature (°C), monthly total rainfall (mm) and daily average solar radiation (MJ m^{-2}) during the experimental period in Sunawal, Nawalparasi, Nepal, (A) 2011 - (B) 2012

(Source: NWRP, 2011 and 2012)

The weather data during cropping season was recorded from the metrological station of National Wheat Research Program (NWRP), Bhairahawa, Rupendhehi (Figure 1; Table 2). Comparatively lower solar radiation were recorded during ripening phase (fertilization to maturity).

Table 2. Weather condition during the experimentation period at Sunwal, Nawalparasi, Nepal

Parameter	Year 2011	Year 2012
Total rainfall (mm)	346.14	123.00
Average Maximum Temperature (°C)	34.87 (25.20 - 38.40)	36.18 (26.80 - 43.20)
Average Minimum Temperature (°C)	22.88 (9.00- 33.40)	25.74 (13.00 – 35.00)
Average Solar radiation (MJ m^{-2})	23.40 (8.40 – 28.00)	24.54 (5.30 – 28.90)

Figure in the parentheses are range

(Source: NWRP, 2011 and 2012)

Experimental design and treatments

The maize crop was grown in the Rice-Mustrad-Maize cropping system. The experiment was done by using strip split plot design, comprising three factors- two crop establishment methods; two varieties, and four N levels, each treatments arranged with three replications (each farmer's field as one replication). Establishment methods and varieties were evaluated in two strips and the N levels were evaluated in the split plots. The experimental plots were 22.68 m^2 (4.2 m × 5.4 m) in size. Two establishment methods were: (i) line sowing at 60 cm row to row and 30 cm plant to plant spacing under no-till with residue retention, i.e. CA (ii) line sowing at 60 cm row to row and 30 cm plant to plant spacing under conventional tillage without residues, i.e. conventional practice were evaluated. In the CA treatments (no tillage and full residue retention), residues of previous crops were retained. Pre-crop residue was applied only in CA treatments. At the start of the experiment with maize in March 2011, mustard residue at 1.32 t ha^{-1} was obtained externally and was equally distributed in all replication before maize sowing. In the second factor, two varieties were evaluated with the use of hybrid and open pollinated variety (OPV) i.e. OPV Rampur Composite and a hybrid Rajkumar. Similarly, four N levels (0, 60, 120 and 180 kg ha^{-1} during 2011, and 0, 80, 160 and 240 kg ha^{-1} during 2012) were evaluated. These N levels were categorized as N_1, N_2, N_3 and N_4 representing from the lowest to highest level for the simplification of the presentation of the results.

Crop management

Glyphosate-47 SL with 5 mL L^{-1} was applied in the CA treatments before seed sowing. Maize seeds were directly sown on the no-till field under CA treatments while field was ploughed two times and planking and leveling was done to bring the soil under good tilth for conventional practice treatments. For both CA and conventional practice, maize seeds were sown on 2 March 2011 and on 26 February 2012 with a seed-cum-fertilizer drill with 20 kg ha^{-1} seed rate, and maintaining a spacing of 60 cm × 25 cm. Atrazine, a pre-emergence herbicide, was applied @ 1.5 kg a.i. ha^{-1} followed by one spot weeding at 20 days after sowing (DAS) in the CA treatment while two hand weeding were done at 23-25 and 42-45 DAS in the conventional practice treatment. Irrigation was applied when crop showed the symptoms of temporary wilting. Recommended dose of phosphorus (26.2 kg P ha^{-1}) and potassium (33.2 kg K ha^{-1}) (AICC, 2017) were applied for all plots as basal while N dose varied among the treatments. In N applied treatments, half dose of N was applied as basal and remaining N was applied at two equal splits (first split at 35 DAS and second split as 42-45 DAS).

Sampling and measurements

Barrenness was measured form the area of 12.6 m^2 (4 rows) at the physiological maturity. Total numbers of barren plants ha^{-1} was counted in each net plot, and it was converted to number of barren plants ha^{-1}. Sterility percentage was measured from the randomly selected ten cobs. Total unfilled length of cob was measured with the help of veneer caliper in cm, and sterility percentage was calculated as:

$$\text{Barrenness percentage} = \frac{\text{Number of barren plants}\text{Number of barren plants}}{\text{Number of total plants} \quad \text{Number of total plants}} \times 100$$

$$\text{Sterility percentage} = \frac{\text{Total unfilled length of cob Total unfilled length of cob}}{\text{Total length of cob} \quad \text{Total length of cob}} \times 100$$

The sampled grain and stover from each plot were used to determine the N concentration. Plant samples were dried at 65^0C for 36 hours and then ground to pass through a 0.5 mm sieve, and kept in brown paper bag for nutrient analysis. Plant samples were analyzed in Soil Science Division of Nepal Agriculture Research Council (NARC), Lalitpur. Total plant N concentration was determined using the Kjeldahl digestion method (Amin & Flowers, 2004). Plant P concentration was determined by a spectrophotometer using Olsen's method after dry ashing followed by its extraction in diluted $H_2SO_{4.}$ Plant K concentration was determined by a flame photometry from the same dry ashing sample so as the analyses by following standard procedures (Table 1).

Statistical analysis

The recorded data were subjected to analysis of variance, and Duncan's multiple range test at α level 0.05 (DMRT) for mean separations (Gomez & Gomez, 1984).. Correlation and regression analysis was done for selected parameters. Dependent variables were subjected to analysis of variance using the R Studio for strip-split plot design. SPSS v.16 was used for the regression analysis, and Sigma Plot v. 7 was used for the graphical representation.

RESULTS

The influence of the establishment methods, varieties, and nitrogen levels on the barrenness and sterility, and their relation to the grain yield of maize were assessed and the results obtained are presented and discussed in the following headings.

Establishment methods, varieties and nitrogen levels influence barrenness and sterility

Both barrenness and sterility were higher by 58.28 and 12.35%, respectively, in the second year as compared to the first year (Table 3) mainly due to higher temperature and low rainfall in 2012 (Figure 1; Table 2). Both barrenness and sterility percentage were slightly higher under conventional agriculture than under CA, but the effect was statistically similar ($p>0.05$) for both the years. Varietal differences with respect to the barrenness was also statistically similar ($p>0.05$) but sterility was significantly ($p<0.05$) influenced during 2012 where Rampur Composite had higher sterility ($p<0.05$) than Rajkumar (Table 3). Nitrogen level had significant effect ($p<0.05$) to the barrenness and sterility percentage during both the years. Increased levels of nitrogen significantly ($p<0.05$) reduced the barrenness and sterility percentage. In 2011 both barrenness and sterility percentage were lowest for 180 kg ha^{-1} and was also significantly ($p<0.05$) lower than 0, 60 and 120 kg N ha^{-1}. Similarly in 2012, these attributes were lowest at highest nitrogen levels (240 kg ha^{-1}). Application of nitrogen at 80, 160 and 240 kg ha^{-1} resulted the statistically similar ($p>0.05$) barrenness and it was significantly higher ($p<0.05$) than nitrogen omission. Increasing nitrogen up to 160 kg ha^{-1} significantly reduced ($p<0.05$) the sterility percentage and, it was statistically similar ($p>0.05$) with nitrogen application of 240 kg ha^{-1} (Table 3).

During the first year of experiment, grain yield was not influenced ($p>0.05$) by establishment methods, but the value was significantly higher in the second year. The grain yield was 23% higher in CA compared with conventional practice. Similarly, grain yield, was significantly higher ($p<0.05$) for hybrid Rajkumar compared to OP Rampur Composite in both the years. Grain yield was higher by 4% in 2011 and 55% in 2012. Grain yield significantly ($p<0.05$) increased with the increased levels of N in both the years. Higher grain yield was obtained from 180 kg N ha^{-1} during 2011, and with the application of 160 kg N ha^{-1} in 2012 compared to other levels though the effects was statistically similar ($p>0.05$) for 160 kg N ha^{-1} and 240 kg N ha^{-1} use in the second year (Table 3).

Table 3. Barrenness (%) sterility (%) and grain yield of maize as influenced by establishment methods, varieties and nitrogen levels at Sunawal, Nawalparasi, Nepal, 2011 and 2012

Treatments	Barrenness (%)		Sterility (%)		Grain yield (t ha^{-1})	
	2011	2012	2011	2012	2011	2012
Establishment methods						
CA	4.48	5.34	13.52	13.25	4.44	3.79
ConA	4.58	9.01	16.85	13.79	4.45	3.09
LSD (=0.05)	ns	ns	ns	ns	0.15	0.08
SEm (±)	0.68	0.86	0.96	0.26	ns	0.51
Varieties						
Rampur composite	5.30	9.02	16.72	15.05^{a}	3.68	2.70
Rajkumar	3.77	5.33	13.66	11.99^{b}	5.20	4.18
LSD (=0.05)	ns	ns	ns	2.53	0.21	0.09
SEm (±)	0.42	0.83	0.60	0.42	1.26	0.57
Nitrogen levels (kg ha^{-1})						
N_1	10.94^{a}	26.92^{a}	21.76^{a}	21.73^{a}	3.13^{d}	1.54^{c}
N_2	3.88^{b}	1.23^{b}	13.26^{b}	16.29^{b}	4.18^{c}	3.40^{b}
N_3	1.91^{c}	0.41^{b}	10.85^{c}	11.92^{c}	4.93^{b}	4.42^{a}
N_4	1.40^{c}	0.14^{b}	8.20^{d}	10.81^{c}	5.55^{a}	4.40^{a}
LSD (=0.05)	1.39	2.91	2.12	2.52	0.15	0.10
SEm (±)	0.48	1.00	0.73	0.86	0.43	0.29
CV, %	36.50	48.20	18.60	19.70	12.00	8.10
Grand mean	4.53	7.17	13.52	15.19	4.48	4.61

Note: CA, conservation agriculture; ConA, Conventional agriculture, N_1, 0 ; N_2, 60; N_3, 120; N_4, 180 kg N ha^{-1} in 2011 and N_1, 0 ; N_2, 80; N_3, 160; N_4, 240 kg N ha^{-1} in 2012; ns, non-significance. Treatments means followed by common letter (s) within column are not significantly different among each other based on DMRT at α level 0.05

The significant interaction of establishment methods and nitrogen levels on barrenness and sterility percentage was observed in the year 2011 (Figure 2). Nitrogen application of 60-180 kg ha^{-1} under both establishment methods significantly reduced ($p<0.05$) barrenness (Figure 2A). Even under the nitrogen omission, significantly higher barrenness was recorded for conventional agriculture than CA. Under both establishment methods, nitrogen omission had highest sterility with significant level ($p<0.0$) reduction, respectively.

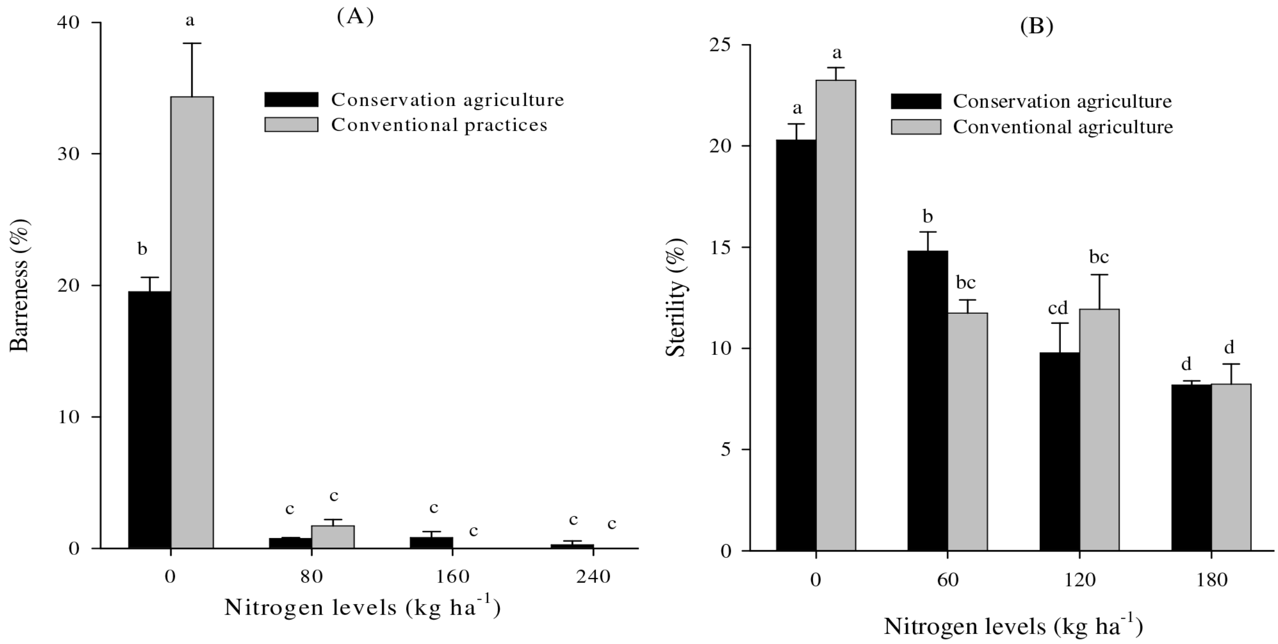

Figure 2. Barrenness (%) and sterility (%) as influenced by interaction of establishment methods and nitrogen levels of maize at Sunawal, Nawalparasi, Nepal, 2011.

Note: Treatments means followed by common letter (s) are not significantly different based on DMRT at α level 0.05

Interaction of varieties and nitrogen levels also influenced the barrenness and sterility (Figure 3). Nitrogen application significantly ($p<0.05$) reduced barrenness for both hybrid and OPV as compared to nitrogen omission plots. At the same time nitrogen omission on OP Rampur Composite resulted the higher ($p<0.05$) barrenness than hybrid Rajkumar on both the years (Figure 3A and 3B). During 2011, N application of 60 kg ha^{-1} and in the year 2012, N application of 80 kg ha^{-1} to hybrid Rajkumar significantly reduced ($p<0.05$) the barrenness, further increasing nitrogen levels had no influenced ($p>0.05$) on the barrenness. But on OP Rampur Composite, nitrogen application up to 180 kg ha^{-1} had significantly reduced ($p<0.05$) the barrenness in the year 2011 (Figure 3A) whereas during the year 2012 effect was significant ($p<0.05$) up to 80 kg N ha^{-1} there after the effect was not significant ($p>0.05$) (Figure 3C). Likewise in the second year, N application of 80 kg ha^{-1} for both OPV and hybrid significantly reduced the barrenness over N omission and was statistically similar ($p>0.05$) to the application of higher dose of N (Figure 3B).

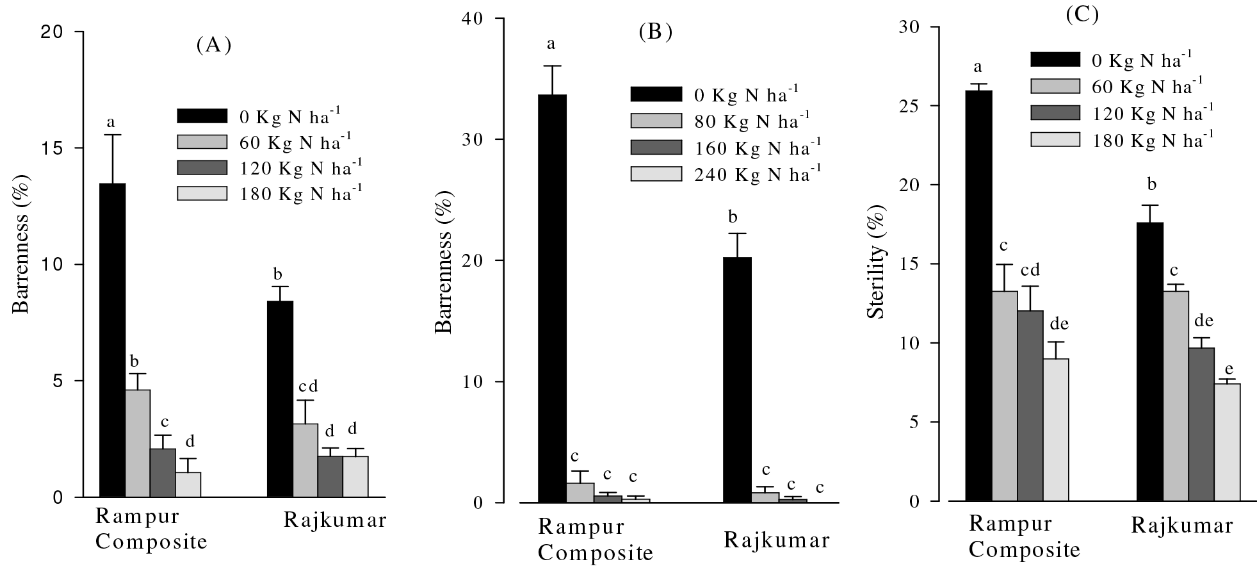

Figure 3. Interaction between varieties and nitrogen levels on (A) barrenness (2011), (B) barrenness (2012) and (C) sterility percentage (2011) of maize at Sunawal, Nawalparasi, Nepal

Note: Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at α level 0.05.

Interaction/combination of varieties and nitrogen levels was significantly influenced the sterility in the year 2011 (Figure 3C). Both for OP and hybrid, sterility was significantly reduced ($p<0.05$) with the application of N compared to the control treatment. Application of 180 kg N ha^{-1} resulted the lowest sterility which was significantly lower ($p<0.05$) than the 0 and 60 kg ha^{-1}, and was statistically at par with 120 kg ha^{-1}. In control treatment, hybrid variety had lower sterility than OP.

Effect of nitrogen levels and nitrogen uptake on barrenness and sterility percentage

Both barrenness and sterility (%) was significantly decreased ($p<0.05$) in linear pattern (Figure 4). With the increased levels of nitrogen, barrenness was drastically reduced as compared to the sterility.

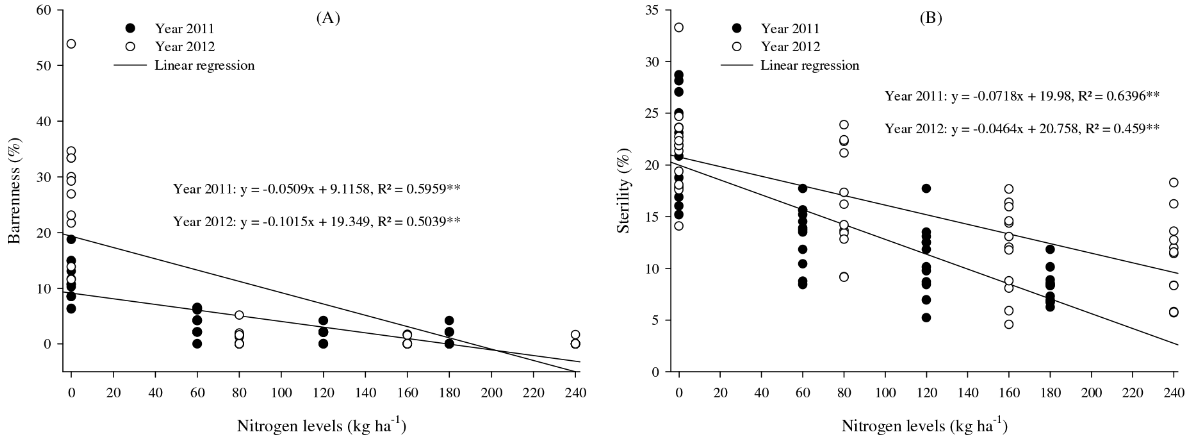

Figure 4. Effect of nitrogen levels on (A) barrenness and (B) sterility of maize at Sunawal, Nawalparasi, Nepal, 2011 and 2012

*Note:**, significant at 0.05 level of significance; **, significant at 0.05 level of significance.

The nitrogen uptake had significant and negative correlation with sterility percentage to both varieties and the years (Figure 5). Rajkumar had higher nitrogen uptake than Rampur Composite, resulting lower sterility of Rajkumar.

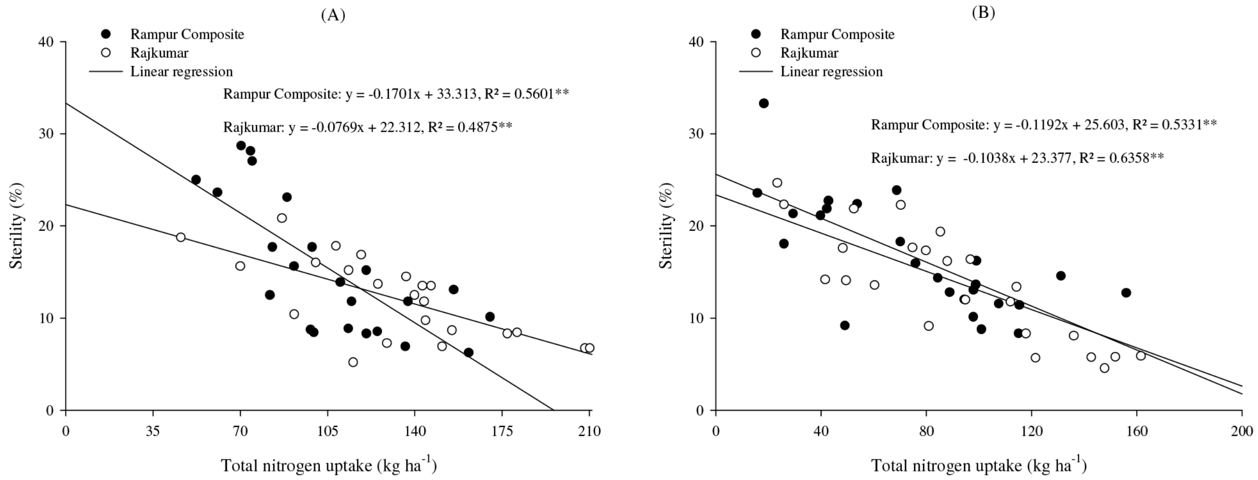

Figure 5. Influence of nitrogen uptake on sterility (%) of Rajkumar and Rampur Composite in (A) 2011 and 2012 (B) at Sunawal, Nawalparasi, Nepal

*Note:**, significant at 0.05 level of significance; **, significant at 0.05 level of significance.

Effect of barrenness and sterility percentage on grain yield of maize

The effect of barrenness and sterility on the grain yield of maize was negative, and significant during both the years. The high level of sterility and barrenness during second years (2012) resulted in less grain yield (Figure 6).

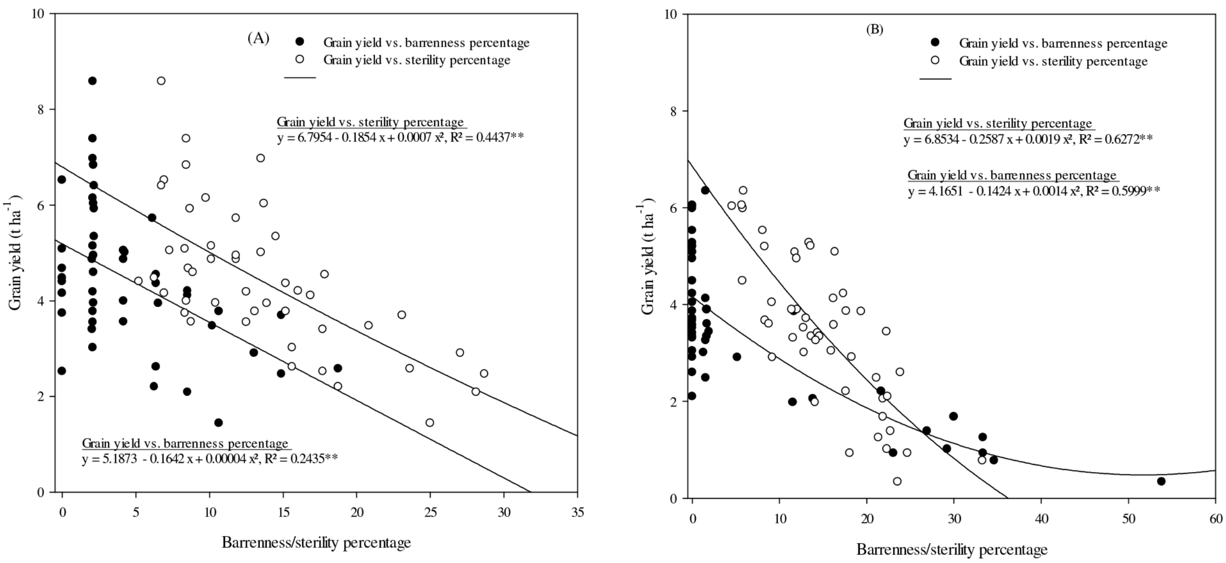

Figure 6. Influence of barrenness and sterility percentage on grain yield of maize (A) 2011 and (B) 2012 at Sunawal, Nawalparasi, Nepal

*Note:**, significant at 0.05 level of significance; **, significant at 0.05 level of significance.

DISCUSSIONS

Barrenness has been reported to occur mainly due to excessive planting density, while sterility may occur due to the biotic and abiotic stress to the plants. Both sterility and barrenness were higher in the second year as compared to the first year in this experiment mainly due to higher temperature and low rainfall in 2012 (Figure 1 and Table 2). A major cause of this could be due to reduction in assimilates flux to the developing ear below some threshold level which is necessary to sustain optimal grain growth (Yadav et al., 2004). Successful grain set in maize requires the production of viable pollen, interception of pollen by the receptive silk, transmission of the male gametes to the egg cell, initiation and maintenance of embryo, and endosperm development (Cairns et al., 2012). All these processes were adversely affected by the high temperature and low moisture.

Pollen production or/and viability is the major factor responsible for reduced fertilization. High temperature could result in the problems with the pollen cell differentiation, anther wall formation and decreased number of silks and florets, kernel abortion (Smith & Zhao, 2016). Pollen produced under high temperature could reduce viability and germination (Kaushal et al., 2016). Water deficit during pollination increased the frequency of kernel abortion in maize (Farooq et al., 2009). Earlier study in this line was such that higher temperature was strongly associated with moisture stress and had reduced pollen water potential, quantity of pollen shed and poor pollen tube germination (Pacini & Dolferus, 2019). When maize plants were exposed lo drought stress at tasseling stage, it caused problems on the pollen cell differentiation and starch accumulation in pollen which resulted the lower viability of pollen and carbohydrate transport to ovary decreased the number of kernels and increased the embryo abortion (Smith & Zhao, 2016). Low rainfall induced the drought stress and higher temperature during the spring season of year 2012, led to these physiological changes in male and female flower resulted in higher barrenness and sterility and low yield. Barutcular et al. (2016) also reported the substantial reduction in yield and yield components such as kernel rows per cob, kernel number per row, thousand kernel weight, kernels per cob, grain yield per plant, biological yield per plant, and harvest index due to heat and drought stresses.

Barrenness and sterility both were lower for hybrid Rajkumar than OP Rampur Composite, but significant ($p<0.05$) only at year 2012 for sterility might be due to poor pollination and insufficient assimilate supply to developing kernels. Hybrid Rajkumar had better nitrogen uptake cope even with the stress condition. DeBruin et al. (2018) also reported that barrenness increase of old cultivars was higher than that of newer cultivars. The modern hybrids had shorter anthesis-silking interval to ensure synchronous and rapid silk emergence and pollination (Li et al., 2011).

Both barrenness and sterility were reduced by nitrogen application and nitrogen uptake in these experiments. Number of grains that developed from the fertilized spikelet was higher under adequate nitrogen levels resulting in low sterility. Nitrogen omission and lower nitrogen levels had pronounced nitrogen stress during pre-flowering resulting lower photosynthesis rate and few number of ear spikelet (potential grains). DeBruin et al. (2018) summarized that increased barrenness under nitrogen limiting conditions results from compromised silk emergence, reduced ear and kernel growth rates, and reduced allocation of nitrogen to the ear. Nitrogen stress during flowering stage, nitrogen stress had resulted kernel and ear abortion (Turc & Tardieu, 2018). Maize plant and ear barrenness decrease as nitrogen applications increase (Chen et al., 2016). Even under the nitrogen omission the hybrid Rajkumar had lower sterility than the OP Rampur composite. It indicated the stability of new cultivars was more than that of old cultivars for adapting to nitrogen change. Compared with older cultivars, newer cultivars maintained shorter anthesis-silking interval, and exerted silks at a more rapid rate and captured assimilate supply for growth when nitrogen becomes limiting (DeBruin et al., 2018).

CONCLUSION

High grain yields of maize were obtained with adaptation of conservation agriculture practice through no-tillage and residue retention. Hybrid Rajkumar variety had yielded higher grain yields with the application of higher nitrogen levels up to 120-160 kg ha^{-1} which was directly related to the lower sterility and barrenness (%). Higher nitrogen uptake with increasing nitrogen levels lowers the sterility and barrenness percentage and improved the grain yield. Hybrid Rajkumar was more stable than OP Rampur Composite even in the low nitrogen application, high temperature and drought, had lower barrenness and sterility, and thus the high grain yield. This findings could be useful for further in-depth research in this direction.

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