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Plant Density Affects the Productivity of Maize / Fingermillet Systems in the Mid Hills of Nepal.

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ABSTRACT

Maize/fingermillet cropping systems are important for advancing sustainable food security in the mid hills of Nepal. Yet recently its productivity has either remained static or declined. Inadequate plant density is one of the major contributing factors to this system's low productivity. A study was conducted to determine the productivity of a maize/fingermillet system under varying maize population densities. Two maize populations were tested: one having a density at harvest of 36000 plants ha^{-1} and another with 53,333 plants ha^{-1}. These two population treatments were implemented on five farmer's fields in the mid hill districts of Parbat and Baglung. Each farm contained four paired plots at two locations. The final number of plants at harvest as well as yield and yield components of both maize and fingermillet were observed from every quadrat at each field. The results showed that a higher initial maize population increased the productivity of the system by approximately150%. However, fingermillet yield was reduced by an average of 32% with increased final maize population from 36000 to 53333 plants ha^{-1}. The recommended plant population of 53,333ha^{-1} is necessary for increasing productivity of maize/millet systems in the mid hills of Nepal.

INTRODUCTION

Maize (*Zea mays* L.) and finger millet (*Eleusine coracana* Gaertin) are the second and fourth most widely produced cereal crops in Nepal, respectively, with over 70% of maize and 75% of fingermillet being produced in the mid-hill regions. Of the total area under fingermillet cultivation, 85% is relayed with maize in Nepal. Maize-millet systems are advantageous to farmers becasue of reduced land preparation and more efficient utilization of moisture, nutrient, and labour resources [12].

Yet low productivity of maize-millet systems (average yields of 2.5 $Mgha^{-1}$ for maize and 1.13 $Mgha^{-1}$ for finger-millet ABPSD [1] is hindering food security in the mid-hills. One factor that contributes to low system productivity is faulty thinning practices that lead to sub-optimal plant populations at harvest. However, information on optimal plant populations is lacking for maize-millet systems in these regions. Therefore, the present investigation was carried-out to determine whether or not increasing maize populations would increase yields in the mid-hills of Nepal.

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MATERIALS AND METHODS

Study site description

The study was conducted in the hill districts of Baglung and Parbat in the villages of Pang and Langgaun, respectively. Soils of both locations were reddish-brown in color, clay-loam in texture and had a pH of 6.0 to 6.5 in Lunggaun and 6.0 in Pang. Total soil NPK was 0.18%, 71ppm and 111mg kg^{-1} in Lunggaun, and 0.21%, 65 ppm, 95mg kg^{-1}in Pang. Soil organic carbon at both locations was 1.6 percent.

Maize was planted at both sites during the second week of April, 2010. Ten tons of farm yard manure (fresh weight) per hectare was applied during land preparation and 40 kilograms of urea (46% N) per hectare was applied as top dressing during knee high stage of the crop. All crops were maintained under rainfed conditions without irrigation.Two manual intercultural operations with the help of local hoe were done in a season; once at 35 days after sowing (DAS) and another at knee high stage. Any remaining management decisions were carried out as per the farmers' existing practices.

Experimental Design and Layout

Two maize population treatments representing conventional farmers' practice (FPP) and research-based recommended practice (RPP) were implemented in this study. The initial maize population for both treatments was 65,000 plants per hectare, whereas the final population at harvest was 36,000 and 53,333 plants per hectare for FPP and RPP treatments, respectively. The final maize population for the FPP treatment was determined based on a field survey carried-out prior to the 2010 maize planting around the villages of Pang and Langgaun in the Baglung and Parbat districts, respectively (See Results & Discussion). The final population for the RPP treatment was determined as per the research recommendation of 53333 plants per hectare. It is important to note that the RPP treatment was thinned to its final density at 30 DAS, whereas the FPP treatment was thinned to its final density as late as 60 DAS according to farmer practice (see *Results & Discussion*). The FPP vs. RPP comparison was carried out on five farmer's fields in both Pang and Laggaun. Every field contained four plots each of both FPP and RPP treatments running parallel in strips. Quadrats were of 5mx5m ($25m^2$) Initial maize population was recorded at 20 DAE and final plant population at harvest. Grain yields of maize and fingermillet as well as yield components and plant height were measured.

Data Analysis

Analysis of variance for plant population and yield parameters of maize and fingermillet were analyzed with GENSTATC Discovery version. Treatments were compared using the "F-test" and any significant differences between treatments were compared by Least Significant Difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Survey Results

The results of the survey taken in 2010 in the areas surrounding Pang and Luggaun revealed that standard farmer practice in these regions is to sow an initial maize plant density of approximately 65,000 and 62,000 plants per hectare, respectively (Table 1). However, the final maize population at harvest is reduced to approximately 36,000 plants per hectare at both locations due to thinning of plants for animal feed (Fig. 1& 2) .Farmers thin their maize fields at approximately 30, 45 and 60 DAS depending on livestock fodder requirements.Other studies have confirmed such plant population fluctuations in the hills of Nepal. Subedi and Dhital [12] found that initial and harvest plant stands in the Western hills of Nepal were 69000±1800 and 37000±1700 plants per hectare, respectively, a 46% reduction from the initial stand. A study conducted in the Eastern hills Tiwari *et al.* [13], showed that the initial mean population was 102, 100, and 38.5% higher than the nationally recommended maize population at three different locations, yet the final mean population at harvst was 45, 42 and 28% less at these same sites, respectively. In the similar study in Central hills, a similar result was found by Bisworkama [3].

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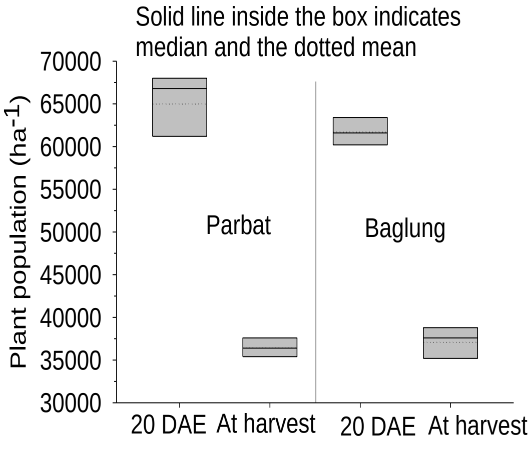

Figure 1: Initial and final plant population

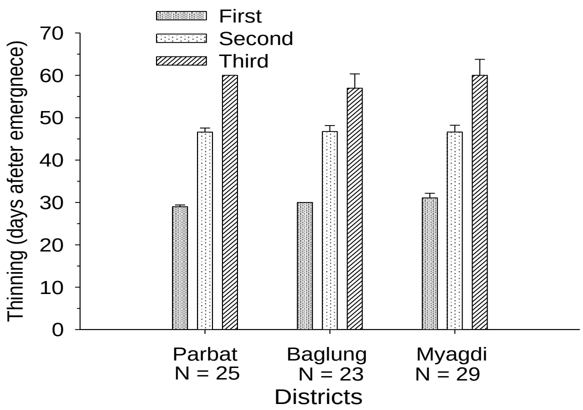

Figure 2: Time of farmer maize thinning

Density Effects on Maize Height

No differences in maize plant height were found due to location, but there was significant variation due to final plant population densities. At both Pang and Lunggaun plant height was reduced by approximately 68% in the FPP treatment relative to RPP (Table 2). Although the RPP treatment had a higher final population, it was thinned at 30 DAS, whereas FPP was thinned around 60 DAS. In light of this, the short stature in FPP was most likely due to a longer and increasingly intense period of intra-specific resource competition during its vegetative stage, a critical time of biomass accumulation. For FPP, the detrimental impact of a high density of plants earlier in the season outweighed any benefits of a lower plant population (relative to RPP) during the reproductive stages of development. This hypothesis has been supported by other studies of rainfed maize [7,11].

Density Effect on Yield Components

Yield components measured included cob diameter and length, kernels per row, kernel rows per cob, and thousand-kernel weight. None of these parameters were significantly different between the Pang and Lunggaun locations except for the number of kernels per row. In contrast, every yield component parameter measured was significantly higher for the RPP treatment than for the FPP (Table). Numerous studies have shown the effect of maize population density on all of the components measured in this study [11,5,14]. Again, greater yield components in RPP can be attributed to lower plant populations earlier in the season relative to FPP (See discussion in *Density Effects on Maize*). Sangoi, et *al*. [9] also found that stress during early growth stages resulting from high maize population density, late developing distal spikelets fail to set kernels because nutrient deficiencies cause delayed silking resulting in little or no pollen availability for fertilization. In the same way, high stand density reduces ear shoot growth resulting in fewer primordial spikelets being transformed into functional florets by the time of flowering. The limited carbon and nitrogen supply to the ear stimulates young kernel abortion immediately after fertilization [9].

Density Effect on Maize Grain Yield

The Pang site had significantly lower yields for both RPP and FPP relative to Lunggaun, most likely due to higher soil fertility of the latter. Furthermore, as is expected in light of the improved yield components of RPP relative to FPP treatments, RPP also showed significantly higher maize grain yields at both locations. Higher densities produced lower maize grain yields as a result of smaller ear size and less number of ears per plant [2]. Other studies have also reported the similar findings [4, 6, 8].

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Table 1. **Plant populations density at harvest**

Location	Maize Population Density FPP	Maize Population Density RPP
	Plants Ha^{-1}	
Lunggaun	35540	52673
Pang	35297	52546
Mean	35419	52610
Location	***	***
Plant Density	***	
LSD	157.5	
CV %	0.7	

Table 2. **Plant Height**

Location	Maize Population Density FPP	Maize Population Density RPP
	Plants Ha^{-1}	
Lunggaun	148.3	214.1
Pang	146.9	216.4
Mean	147.6	215.25
Location	NS	NS
Plant Density	***	
LSD	4.83	
CV %	5.1	

Table 3. **Yield components: cob length, diameter and kernel rows per cob, kernels per row, 1000 grain weight**

Location	Cob Length		Cob Diameter		Kernel Rows Cob^{-1}		Kernels Row^{-1}		1000 Grain Weight	
	FPP	RPP	FPP	RPP	FPP	RPP	FPP	RPP	FPP	RPP
	Centimeter		Centimeter		Number		Number		Grams	
Lunggaun	15.29	19.06	3.453	3.995	14.96	18.84	330.8	407.0	286.13	290.86
Pang	15.54	18.95	3.441	4.033	14.73	18.68	314.9	383.1	286.96	291.02
Mean	15.42	19.01	3.447	4.014	14.85	18.76	322.9	395.1	286.55	290.94
Location	NS	NS	NS	NS	NS	NS	***	***	NS	NS
Plant Density	***		***		***		***		***	
LSD	0.435		0.182		0.47		4.51		2.431	
CV %	4.9		9.4		5.4		4.9		1.6	

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Density Effect on Fingermillet Grain Yield

Grain yields of fingermillet varied between sites with Lunggaun having the higher yields. As with the maize crop, greater fingermillet yields was most likely due to greater soil fertility. Unlike the maize crop, however, FPP showed significantly higher fingermillet grain yields than RPP, although the differences were not as large (Table 4). Yields were decreased by 28% and 36% in RPP relative to FPP. One probable cause for this was due to greater shading of relayed fingermillet by maize as a result of higher final plant density in the RPP treatments. Conversely, high competition early in the season due to delayed thinning in the FPP treatment decreased maize yields, but low competition late in the season due to a low plant population resulted in higher fingermillet yields. Increased plant density resulted higher grain yield of maize per unit area [8].

Table 4. **Maize and Fingermillet Grain Yield**

Location	Maize Grain Yield		Fingermillet Grain Yield	
	FPP	RPP	FPP	RPP
	Mt Ha^{-1}		Mt Ha^{-1}	
Lunggaun	1.399	3.582	1.101	0.857
Pang	1.365	3.408	1.088	0.800
Mean	1.382	3.495	1.095	0.829
Location	NS	*	*	***
Plant Density	***		***	
LSD	0.049		0.012	
CV %	3.9		2.3	

Density Effect on Total Grain Yield

Examining the total grain yield of both fingermillet and maize combined, it is clear that the slight increase in fingermillet grain yield due to the low density, FPP was far outweighed by maize grain yields found in the high density RPP treatments (Table 5). RPP showed a 78% and 72% total grain yield increase in Lunggaun and Pang, respectively.

Table 5. **Combined maize and fingermillet grain yield**

Location	Combined Grain Yield	
	FPP	RPP
	Mt Ha^{-1}	
Lunggaun	2.500	4.439
Pang	2.453	4.208
Mean	2.477	4.324
Location	NS	***
Plant Density	***	
LSD	0.048	
CV %	0.067	

CONCLUSION

The results of this study have demonstrated two very important concepts: a) Proper timing of thinning is crucial to maximizing maize grain yield. The early stages of maize development are sensitive to competition and for resources. Thus, fields not thinned until 60 DAS will result in reduced maize yields; b) Maize population density significantly influences grain yield components and thus grain yield. Based on this study, the common farmer practice of 36,000 plants per hectare (final density) is too low to achieve maximum grain yields. Maintaining a final plant population at approximately 53,000 plants per hectare has shown to greatly increase yield.

The density vs. yield relationship most likely follows a bell-shaped curve, that is, there is some optimal density at which grain yield is maximized and any deviations from this density (either lower or higher) will result in decreased yields. In light of this, further research that includes more density treatments needs to be conducted so as to pinpoint this optimal density for this region and its maize varieties.

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REFERENCES

1. ABPSD. Agri-Business Promotion and Statistics Division. Ministry of Agricultural Development, Government of Nepal, Kathmandu, Nepal. 2012
2. Akbar H, P Shah, AZ Khan, H Saeed and M Munir. Biomass, grain yield and harvest index as criteria for comparing corn types at different nitrogen levels and planting densities. Sarhad J Agric. 1996; 12:117-121.
3. Bishwokarma SB .Survey of Farmer Production Practices in the Maize/Millet Cropping Pattern in the Mid-hills.In:Profile of Hill Agriculture Research Project, Kathmandu, Nepal. 2001; 31p.
4. Dien DH. The performance of Hybrid KSX 3853 under different planting density and fertilizer level. In: Seed production of maize in Asia and research in crop management. Nakhonratehasima, Thailand. 1997; 167-169.
5. Iowa .How a Corn Plant Develops. Iowa State University of Science and Technology-Cooperative Extension Service. Ames, Iowa. Report Number 48.Subedi, K D, B P Tripathi, B K Gyawali,T B Gurung, K Adhikari, R Khadka, R R Pandey, M Subedi, P M Shakya, D M Shakya, B B Basnet, J P Jaisawal, T P Pradhan and B K Shrestha. 1991. Maize/millet relay intercropping system in the western hills of Nepal: Report of a Samuhik Bhraman. In:LARC Working Paper No. 15/91. Lumle Regional Agricultural Research Centre, Kaski, Nepal. 1993
6. Malaviarachchi MAP, KM Karunarathne, SN Jayawardane. Influence of plant density on yield of hybrid maize under supplementary irrigation. J. Agric. Sci. 2007; 3:2.
7. Sangakkara U R, P S Bandaranayake, J N Gajanayake, P Stamp. Plant populations and yield of rain-fed maize grown in wet and dry seasons of the tropics. Maydica. 2004; 49: 83-88.
8. Sadeghi M, A Naderi, L Shahram, GA fathi. Evaluation of plant population density on growth, grain yield and yield components of four maize hybrids. Adv. Envi. Bio. 2012
9. Sangoi L . Understanding plant density effects on maize growth and development: an important issue to maximize grain yield. Ciencia Rural. 2001; 31(1):159-168.
10. Sarlangue T, FH Andrade, PA Calvino, LC Purcell. Why do maize hybrids respond differently to variation in plant density? Agron J. 2007; 99: 984-991.
11. Sharifi R S, M Sedghiand A Gholipouri. Effect of Population densityon yield and yield attributes of maize hybrids. Res J Bio Sci. 2009; 4 (4):375-379.
12. Subedi KD, BK Dhital. Plant population dynamics of maize under farmers'management in the Western hills of Nepal. Exp Agr. 1997; 33: 189-195.
13. Tiwari TP, RM Brook, P Wagstaff, FL Sinclair. The Agriculture Environment of Maize/Millet with Tree System in the Eastern Middle hills of Nepal. In: Sustainable Maize Production Systems for Nepal. Proceedings of Maize Symposium. 3-4 December, 2001, Kathmandu, Nepal. 2001
14. Zamir MSI, AH Ahmad, HMR Javeed, T Latif . Growth and yield behaviour of two maize hybrids (*Zea mays* L.) towards different plant spacing. Cercetări Agronomiceîn Moldova. 2001; 114(2): 33 40.