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Original Research Article

Modified Double Row Spacing and Fertilizer Rate for Improved Productivity of Glutinous Corn

Dr Dionisio S. Bucao[1*], Jilves I. Jimenez[2]

[1]Supervising Education Program Specialist, Mariano Marcos State University, 2906
[2]School Farm Demonstrator, Mariano Marcos State University, 2906

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Abstract: Various high yielding glutinous corn varieties have been developed and NSIC registered, however, the national and regional yield averages are still very low. A study therefore, was conducted to increase the yield of glutinous corn in Ilocos Norte though modification of planting distance and fertilizer rate. Experimental setups were established for two consecutive dry seasons from 2019-2021 which were laid-out in Split-Plot following the randomized complete block design with three replications using MMSU Glut 1 variety as test plants. Soil pH level of the soil before and after harvest from a depth 0-20 cm and 21-40 cm was increased from 7.26 to 7.52 and 7.33 to 7.60, respectively. MDR plots have higher OM at the 0-20 cm depth by 11.67% to 15.55% as N levels applied increase from 120 to 200 kg N ha^{-1}. At 90 DAE, glutinous corn fertilized with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} was significantly taller by 4.2% and 10.77%; higher ear height by 9.6% and 21.40%, longer ear length, and wider ear diameter than those applied with 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} and unfertilized corn plants, respectively. Heavier ear weight and larger seed size were attained from treatment combination of PD 75 cm x 20 cm and FR of 200-100-100 kg $NP_2O_5K_2O$ kg ha^{-1} and PD – MDR and FR of 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}. Combination of PD (MDR) and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained the highest shelling percentage of 93.23%. PD and FR significantly affected the agronomic fertilizer use efficiency (AFUE) of glutinous corn. Application of FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} provided glutinous corn an increased in yield of 17.5% (PD 75 cm x 20 cm), 55% (PD 60 cm x 20 cm) and 105% (PD 80:30 cm x 20 cm) over FR 180-80-80 kg $NP_2O_5K_2O$ ha^{-1}, FR 120-60-60 kg $NP_2O_5K_2O$ ha^{-1}, and the unfertilized, respectively. Treatment combination of PD MDR and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} gave glutinous corn higher yield by 28.10% using the combination of PD 60 cm x 20 cm and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} and 29.53% using combination of PD 75 cm x 20 cm and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}, and 79.07% higher than the recommended practice FR 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} and PD 75 cm x 20 cm. Combination of PD MDR and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} gave the highest net profit ha^{-1} (PhP 86,075.00) and lowest production cost kg^{-1} seeds. As compared to the conventional practices, it has a net return of PhP 58, 971.00 and a benefit-cost ratio of 5.76. Hence, it can be used as a new strategy in increasing the productivity of MMSU Glut 1 corn.

Keywords: Fertilizer Rate, Modified Double Row, MMSU Glutinous Corn, Ilocos Norte.

RATIONALE

Corn (*Zea mays* L.) ranks second to rice as staple food in the Philippines and it accounts 20% of the country's population. Its production can be described as highly intensified due to forgoing decline of soil fertility and occurrence of insect pest and diseases as one of the impacts of climate change. The Philippine has an average volume of corn production of about 7.96 M metric tons (mt) from 2018 to 2020 with an area of 2.53 M ha (PSA, 2021). Volume of production on yellow corn accounts about 74 percent and 26 percent for glutinous corn from a cultivated areas of 1.41 M and 1.12 M ha, respectively.

There are wide arrays of NSIC registered glutinous corn varieties grown in the Philippines mainly

***Corresponding Author:** Dionisio S. Bucao
Supervising Education Program Specialist, Mariano Marcos State University, 2906

used as an alternative staple food particularly in Visayas and Mindanao and for cornick production in Northern Luzon. These varieties have high potential yields ranging from 4.26 t ha^{-1} (Mt. Apo Gold 800w) to 8.93 t ha^{-1} (USM Var 22). However, the national average yield of glutinous corn is only less than 2 t ha^{-1} which is far below their potential yields. PSA (2021) reported that Mindanao, Visayas, and Bicol in Luzon are the main producers of white corn but the yield ranged only from 1.32 – 2.62 t ha^{-1}, 0.85 – 1.86 t ha^{-1}, and 1.0 – 2.91 t ha^{-1}, respectively. Also, PSA data from 2016-2020 show that the national yield average of glutinous corn is only 1.83 t ha^{-1} while Ilocos Region has 3.71 t ha^{-1} which is higher by 103% which obtained the highest yield average in the Philippines. Ilocos Norte, however, has the lowest yield average among the four provinces in Ilocso Region and even lower than the regional average with only 3.62 t ha^{-1}.

Meanwhile, increasing rice importation has been observed due to lack of local supply due to high intake of rice with an average per capita consumption of 118.81 kg annually or 325.5 grams of milled rice daily (DA, 2020). This has caused also the prevalence of type 2 diabetes cases at an increasing rate among Filipinos (Tan 2016). Earlier in 2011, Sec. Proceso Alcala of the Department of Agriculture (DA) encouraged the Filipinos to eat rice-corn mixture to provide extender for rice and reduce volume of imports and minimize the prevalence of diabetes because corn has low glycemic index than rice (UPLB, 2018).

MMSU Glut 1 (*Zea mays* var. ceratina) or NSIC Cn 251 is one of the corn cultivars being grown in Ilocos Region and was developed by MMSU. It is highly adaptable to agro–climatic conditions prevailing in Luzon areas particularly in Quirino Province and in Ilocos Region and can adopt well during the dry and wet seasons Remolacio *et al*., ( ). It has a potential yield of 5. 61 t ha^{-1} due to longer ear length and a high shelling percentage recovery. It can grow up to two meters height and matures at 98 days. It is highly acceptable when eat as boiled and processed as cornick. With the increasing demand of cornick locally and internationally, there is a need to increase the supply of glutinous corn to sustain the industry. As a response to the call of DA to boost the production of glutinous corn and help address food security, health, and wellbeing of Filipinos, MMSU needs to develop a production system that would increase the productivity of glutinous corn.

Farmers often apply high N fertilizer than what is required by the crop (Gumtang, 2009). This technique does not often increase the grain yield and profitability of the crop but affects the economic benefits due to high production cost (Zhang *et al*., 2020; Du *et al*., 2021), low nitrogen use efficiency, and promote environmental degradation (Wu *et al*., 2017). The need to optimize fertilizer management during the corn growth stages is important to increase fertilizer use efficiency, improve grain yield, and environmental soundness (Pareja-Sánchez *et al*., 2019). Similarly, Increased planting density through altering planting distances generally stimulates crop yield (Dai, J. L. *et al*., 2015; Li *et al*., 2016). Increasing planting density may balance the adverse effects of low N application on crop productivity (Huang *et al*., 2018). The improved grain yield per unit area of modern corn due to the increased plant density is more favored than the improved grain yield per plant (Pioneer, 2015). A reasonable increase of planting density and supplying adequate N application are significant practices to increase grain yield of corn (Du, 2021). Proper cultural management practices must be studied with the goal of attaining the yield potential while determining the optimum nutrient requirement of corn (Baclig, 2003).

Objectives

Generally, the study aimed to determine the effect of modifying the planting distance and fertilizer rate of glutinous corn to increase productivity.

Specifically, it aimed to:

1. Evaluate the effect of the different planting distances on the growth and yield performance of glutinous corn;
2. Determine the effect of fertilizer rates on the growth and yield performance glutinous corn;
3. Determine the best treatment combination of planting distance and fertilizer rate; and
4. Analyze the profitability of glutinous corn production as affected by varying planting distance and fertilizer rate.

Conceptual Framework

The health condition or robustness of the glutinous corn is dependent on the planting distance and the fertilizer rate being applied. Also, nutrient availability and the photosynthetic activity of the corn plant are affected by planting density. With these, the growth as well as the yield and yield components performance of glutinous corn are affected. Thus, the different developmental stages of the glutinous corn are ultimately like the days to tasseling, silking, and maturity. Ultimately, the yield is affected which will determine the profitability of the treatments used in the study (Figure 1).

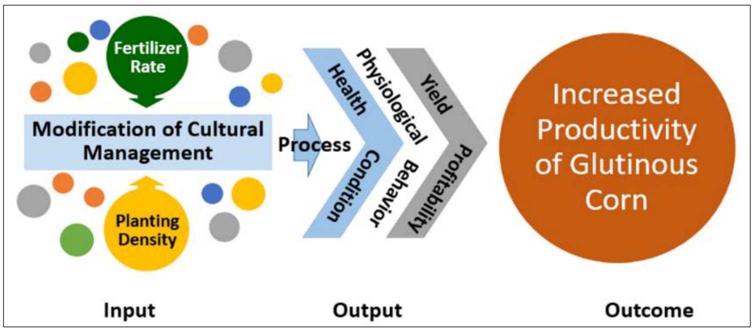

Figure 1: Conceptual framework of the study

METHODOLOGY

Locale of the Study

The study was conducted at the experimental farm of the Mariano Marcos State University (MMSU), City of Batac, Ilocos Norte using MMSU Glut1 corn (NSIC Cn 251) in two dry seasons cropping, *i.e.*, from November 2019 to April 2021. The area is rainfed and was grown to rice during the preceding wet season. The experimental corn plants were supported with groundwater as source of irrigation through shallow tubewell throughout its growth stages. On November 2020 – April 2021, the area received a total rainfall of 108.6 mm, open pan evaporation ranged from 0.5 to 14.3 mm day^{-1} while minimum and maximum air temperatures ranged from 15.2 to 27.0°C and 26.0 to 36.1°C, respectively.

The soil is a Vertisol and classified under San Fernando series. It is relatively deep, clayey in texture and gray to black on the surface and dark gray to black underneath. Prior and after the conduct of the study, a soil analysis at the 0 – 20 cm layer, the soil's bulk density was 1.35 g cm^{-3} and the pH is 7.26. The concentration of the major nutrients is summarized in Table 1. Based on the nutrient availability index of the Bureau of Soils (PCARR, 1978), N content is very low, organic matter, very low; available P, low and very low at 20-40 cm depth, and exchangeable K, adequate.

Table 1: Soil analysis in the experimental area prior to the conduct of the experiment

PARAMETER	METHOD OF ANALYSIS	SOIL DEPTH (cm)	
		0-20	**20-40**
Total N, %	Modified Kjeldahl	0.09	0.05
Organic Matter, %	Graham Colorimetric	1.80	0.92
Available P, ppm	Modified Truog	10.02	1.35
Exchangeable K, ppm	Ammonium Acetate	481.74	320.53
pH	Potentiometric, 1:1 soil water ratio	7.26	7.33
Bulk density, g cm^{-3}	Core method	1.35	1.33

Note:

Organic Matter, %C	%N	Available Phosphorus (ppm)	Exchangeable Potassium (ppm)
Very high - >20	>10	High – >60	High – >250
High – 10-20	0.6 – 0.1	Medium – 20-60	Medium – 175-250
Medium – 4-10	0.3 – 0.6	Low – 10-20	Low – 100-175
Low – 2-4	0.1 – 0.3	Very low – <10	Very low – <100
Very low - <2	<0.1		

Experimental Design and Variable of the Study

The field experiment was laid-out in a split plot following a Randomized Complete Block Design with three replications. The planting density was assigned as the main plot and the fertilizer rate as sub-plot. Each experimental unit has an area of 32.0 m^2 (8m x 4m). Following were the treatments:

A. Main Plot: Planting distance (PD)
PD_1 – 75 cm x 20 cm (control) PD_2 – 60 cm x 20 cm PD_3 – 80:30 cm x 20 cm (MDR)
B. Sub Plot: Fertilizer Rate (FR)
FR_1 – 0 - 0 - 0 (control) FR_2 – 120 – 60 – 60 kg $NP_2O_5K_2O$ ha^{-1} FR_3 – 160 – 80 – 80 kg $NP_2O_5K_2O$ ha^{-1} FR_4 – 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}

The 120 – 60 – 60 kg $NP_2O_5K_2O$ ha^{-1} fertilizer rate is the recommended rate for corn in the Ilocos while the 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} is the recommended for hybrid corn used by Cargill, and split in 3 apploication.

Agronomic Fertilizer Use Efficiency (AFUE)

The AFUE was computed to measure the efficiency of the applied fertilizer at varying rates. This was calculated as follows:

$$AFUE = \frac{\text{Yield (adj) with fertilizer – yield (adj) w/o fertilizer}}{\text{Amount of fertilizer applied}}$$

Cost and Return Analysis

Cost and return analysis of glutinous corn was computed per treatment in the different plant densities at varying fertilizer rates. The production cost and return for each treatment was computed based on the prevailing cost of labor and farm supplies during the conduct of the study.

Analysis of Data

Data from the experiment were subjected to the Analysis of Variance using Statistical Tool for Agricultural Research (STAR) 2.0.1. Comparison of means was done using the Least Significant test at 0.05 level of significance. Also, correlation analysis was conducted to determine the Pearson coefficient which defines the nature of the link between the yield and the growth parameters and yield components. Positively and significantly correlated variables were subjected to linear regression analysis to quantify the contribution of each explanatory variable.

RESULTS AND DISCUSSIONS

Soil Fertility

Table 2 shows the chemical properties of the collected soil samples gathered before and after the conduct of the study. The pH level of the soil before and after harvest from a depth 0-20 cm and 21-40 cm was increased from 7.26 to 7.52 and 7.33 to 7.60, respectively which might be attributed to the quality of the irrigation water applied. Soil organic matter on the other hand decreased s in zero fertilizer plots after harvest while a significant increase in OM at 0-20 cm depth was observed in MDR plots with fertilizer regardless of the amount of N applied. MDR plots have higher OM by 11.67% to 15.55% as N levels applied increase from 120 to 200 kg N ha^{-1}. At the subsoil (21-40 cm), lower percentage of SOM was observed both before and after harvest compared at the topsoil. Although, with fertilizer plots have higher SOM than the unfertilized plots. Technically, SOM accrues mostly in topsoil (Six *et al*., 2002) since it directly receives input from organic litter especially that these plots were under MDR treatment which received higher corn plants density than the other treatments. Kunlanit *et al*., (2020) found out that rice paddy had higher SOM accumulation in topsoil than subsoil in all study sites due to input of rice stubbles remaining after harvesting. Balik *et al*., (2022), pointed out that SOM is influenced by a range of soil-climatic conditions, soil management practices, kind of crops planted, fertilization, and among others. In addition, agricultural crops vary significantly in the quantity and quality of post-harvest residues and root biomass.

Before planting, the P level of the area had 10.02 ppm at the topsoil and 1.37 ppm at the subsoil which are considered low and very low, respectively (PCAAARRD, 2013). After harvest however, significant P depletion was observed on the topsoil in all treatments which ranged from 1.32 ppm to 9.09 ppm with the lower range observed in MDR plots regardless of the fertilizer rates applied. The same trend was observed in the subsoil although P depletion was not substantial. This indicates that like N, the availability P in soils is also limiting, hence, proper amount of N and P should be applied. Likewise, K depletion was not substantial both on the topsoil and subsoil. This can be attributed to the parent materials of soils in Ilocos Norte where exchangeable K is adequate.

Table 2: Chemical analysis of the collected soil samples in the experimental area before and after the conduct of the study

TREATMENT		SOIL CHEMICAL PROPERTIES				
FR, kg NP_2OK_2O ha^{-1}	**PD, cm**	**pH**	**%OM**	**%N**	**P (ppm)**	**K (ppm)**
0 cm - 20 cm	**BEFORE PLANTING**					
		7.26	1.8	0.09	10.02	481.74
	AFTER HARVESTING					
0-0-0	75 x 20	7.54	1.54	0.06	4.91	417.02
	60 x 20	7.56	1.35	0.06	4.69	420.11
	80:30 x 20	7.66	1.54	0.07	4.21	367.83
120-60-60	75 x 20	7.48	1.62	0.08	2.28	435.04
	60 x 20	7.54	1.76	0.07	2.77	425.08
	80:30 x 20	7.53	2.01	0.08	1.32	385.26
160-80-80	75 x 20	7.45	1.71	0.08	2.53	430.54
	60 x 20	7.47	1.84	0.09	8.69	430.32

	80:30 x 20	7.58	2.05	0.10	1.94	377.80
200-100-100	75 x 20	7.43	1.80	0.10	9.09	426.03
	60 x 20	7.40	1.92	0.10	8.29	435.55
	80:30 x 20	7.62	2.08	0.10	2.56	370.32
21 cm - 40 cm	**BEFORE PLANTING**					
		7.33	0.92	0.05	1.37	320.53
	AFTER HARVESTING					
0-0-0	75 x 20	7.49	0.89	0.04	0.69	283.20
	60 x 20	7.66	0.84	0.04	0.52	228.43
	80:30 x 20	7.63	0.71	0.03	0.37	211.00
120-60-60	75 x 20	7.40	1.16	0.06	1.06	268.26
	60 x 20	7.66	1.07	0.05	0.51	268.26
	80:30 x 20	7.72	0.93	0.05	0.42	211.00
160-80-80	75 x 20	7.46	1.04	0.07	1.16	271.90
	60 x 20	7.67	1.11	0.07	1.24	199.80
	80:30 x 20	7.68	1.07	0.05	1.14	245.96
200-100-100	75 x 20	7.53	1.13	0.08	1.25	275.73
	60 x 20	7.68	1.09	0.08	1.17	188.60
	80:30 x 20	7.63	1.02	0.05	1.15	263.49

Growth Performance

Plant Height

Analysis of variance of corn height at 30 DAP did not show significant differences among treatment means both the PD and FR and their interaction (Table 3). Numerically however, corn planted at PD 60 cm x 20 cm were taller (115.74 cm) than the control (113.65 cm) and MDR (112.88 cm) treatments. Conversely, corn height increases as FR increases ranging from 107.53 cm to 117.84 cm. At 60 and 90 DAP PD did not show significant differences. FR however, show significant differences on corn height in both observation periods but not of their interactions. At 60 DAP, the height of fertilized corn plants was comparable regardless of FR applied with height ranging from 205.63 cm – 207.17 cm. but significantly taller than the unfertilized with only 193.36 cm. At 90 DAP, corn plants applied with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (211.01 cm). significantly taller than those applied with 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} (202.42 cm) and unfertilized corn plants (190.50 cm) but comparable with those applied with 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} (205.90 cm). Similar results were reported by Amin (2011) where corn plants have positive response to nitrogen fertilizer applications in terms of height.

Table 3: Agronomic performance (Plant height at 30, 60, 90 DAP, ear height and stem diameter) of MMSU Glut 1 corn planted in different planting distances applied with different recommended fertilizer rate.

TREATMENTS	Plant height						Ear height (cm)		Stem Diameter (cm)	
	30 DAP (cm)		60 DAP (cm)		90 DAP (cm)					
PLANTING DISTANCE (PD)	ns		ns		ns		ns		ns	
75 X 20	113.65		200.69		202.18		103.39		2.21	
60 X 20	115.74		203.64		203.53		106.04		2.02	
80:30 X20	112.88		207.45		201.66		107.65		2.02	
FERTILIZER RATE (FR)	ns		**		**		**		ns	
0-0-0 (control)	107.53		193.36	b	190.50	c	93.61	c	1.95	
120-60-60	114.46		205.63	a	202.42	b	103.68	b	2.13	
180-80-80	116.52		209.54	a	205.90	ab	111.85	a	2.10	
200-100-100	117.84		207.17	a	211.01	a	113.64	a	2.15	
PD X FR	ns		ns		ns		ns		ns	
CV (a) % CV (b) %	8.91 9.92		6.44 3.52		4.70 4.02		7.24 6.47		7.51 11.05	
Means marked with the same letter in a column are not significantly different using $HSD_{0.05}$										
*	= significant at 5%									
**	= significant at 1% level									
ns	= not significant									
CV	= Coefficient of variance									

Ear Height and Stem Diameter

ANOVA showed that PD did not affect the corn ear height but significantly affected by FR. Corn plants received with the two highest FR (200-100-100 and 180-60-60 kg kg $NP_2O_5K_2O$ ha^{-1} were significantly obtained taller ear height with 113. 64 cm and 111.85 cm, respectively than those applied with the recommended rate (103.68 cm) and the control (93.61 cm). Gasim (2001) indicated that the increase in plant height with N fertilizer because it promotes plant growth, increases the number and length of internodes which results in progressive increase in plant height affecting the ear height. No significant interaction observed on the main plot and the subplot.

The stem diameter of corn was not affected by either of the factors or their interaction. Although, numerically, the recommended planting distance (control) showed wider stem diameter of corn because of wider spacing between rows. Corn plants applied with FR of 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained the wider stem diameter compared to those applied with lower FR or no fertilizer. The result was not inconformity with the previous studies conducted by Koul (1997) who reported that addition of N increased stem diameter. This can be attributed to several factors such as the difference in soil quality, PD and climatic conditions.

Yield and Yield Components

The ear length, ear diameter, kernel rows, and ear weight of MMSU glut 1 corn were not affected by PD although the control which has a wider spacing obtained higher value numerically (Table 3). The same result was obtained by Zeleke *et al*., (2018) that planting densities did significantly influence the ear length of corn across all experimental locations. However, result of their study on ear diameter significantly affected by PD which differ from the present study although similar trend was observed. They claimed that corn ear diameter decreased with the increment of PD.

Conversely, FR showed highly significant effect on the above yield components of corn except kernel rows. Under ear length, longer corn ears was obtained from higher FR treatments, 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (15.88 cm) and 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} (15.16 cm) than the recommended rate (14.32 cm) and the unfertilized treatment (10.88 cm). Ear diameter of corn significantly increased as the level of FR increases. FR of 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (5.23 cm) obtained the largest and the unfertilized corn produced the smallest diameter with only 3.96 cm. Interaction effect of PD and FR was observed only on ear weight. Results revealed that corn ear weight was increasing as FR increases regardless of the PD. However, treatment combination of PD 75 cm x 20 cm and FR of 200-100-100 kg $NP_2O_5K_2O$ kg ha^{-1} produced the heaviest ear weight with 124.36 g but not significantly different with the combination of PD – MDR and FR of 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} with 120.81 g. The PD 60 cm x 20 cm in combination with FR of 200-100-100 kg $NP_2O_5K_2O$ kg ha^{-1} produced the lightest ear weight with 108.45 g which might be due to the overcrowding or shading effect caused by the closed planting distance. Results of researches conducted by Ramachandrappa *et al*., (2004), Kar *et al*., (2006), Azam *et al*., (2007), and Durga *et al*., (2012) described that higher corn ear dimensions were attained at wider plant spacing in combination with higher fertilizer dose of NPK.

Table 3: Ear length, ear diameter, kernel rows and ear weight of MMSU Glut 1 corn planted as affected by varying planting distance and fertilizer rate.

TREATMENTS	EAR LENGTH (cm)		EAR DIAMETER (cm)		KERNEL ROWS		EAR WEIGHT (g)	
PLANTING DISTANCE (PD)	Ns		ns		ns		ns	
75 X 20	14.34		4.71		12		98.72	
60 X 20	13.92		4.56		12		90.64	
80:30 X20	13.91		4.66		12		91.99	
FERTILIZER RATE (FR)	**		**		ns		**	
0-0-0 (control)	10.88	c	3.96	c	12		58.68	d
120-60-60	14.32	b	4.61	b	12		94.79	c
180-80-80	15.16	a	4.78	b	12		102.10	b
200-100-100	15.88	a	5.23	a	12		117.87	a
PD X FR	Ns		ns		ns		**	
CV (a) % CV (b) %	7.96 5.19		3.84 5.86		6.33 3.13		11.56 5.78	
Means marked with the same letter in a column are not significantly different using $HSD_{0.05}$								
*	= significant at 5%							
**	= significant at 1% level							
ns	= not significant							
CV	= Coefficient of variance							

Seed Size (G)

The seed size of MMSU Glut 1 corn was based on the weight of 1000 kernels. Result shows that both the main plot and the sublot significantly affected the seed size of corn but not their interaction (Table 4). Corn plants under PD 75 cm x 20 cm (305.33 g) and PD MDR (304.25 g) treatments significantly produced larger seeds than those under PD 60 cm x 20 cm with 297 g per 1000 seeds. Zeleke *et al*., (2018) reported that PD significantly influenced the seed size. Higher kernels per cob were produced in wider spacing or lower density than closer spacing or higher planting density. This result was in accordance with Abuzar *et al*.,

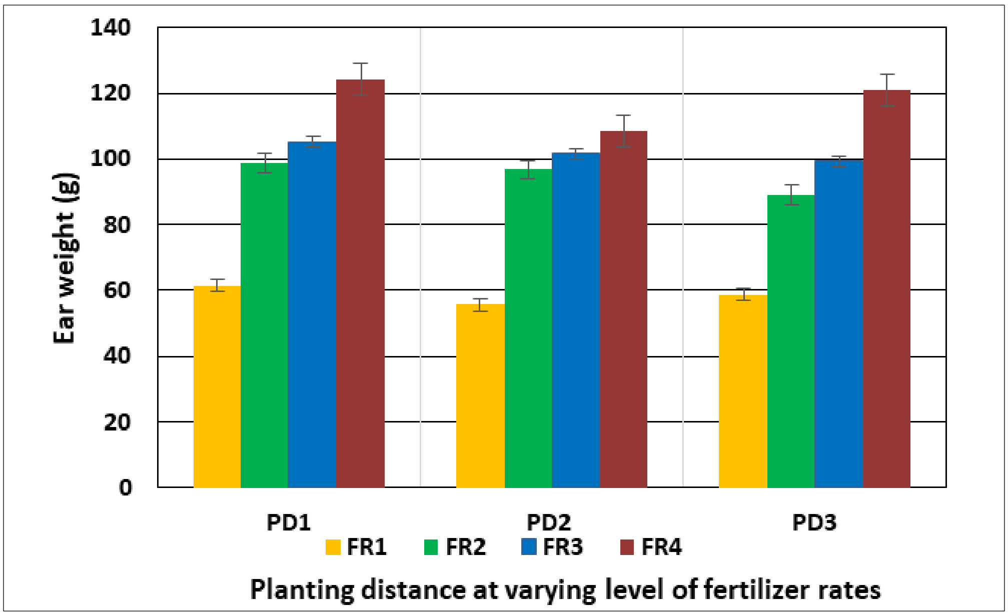

Figure 1: Interaction effect between planting distance and fertilizer rate on the ear weight of glutinous corn.

(2011) and Jan and Amanullah (2002) who reported that an increase in plant density resulted in the decrease number of kernels per cob. This can be attributed to the availability of more resources (i.e. sunlight, nutrient, moisture) to plants on account of low planting density.

Conversely, increasing amount of FR applied in corn plants produced heavier 1000 seed weight than the control. It was observed that FRs 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} and 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} produced a comparable seed size with 317.89 g and 309.44 g, respectively. Giving a size advantage from 6.8% to 12.02% over those applied with the recommended FR (120-60-60 kg $NP_2O_5K_2O$ ha^{-1}) and the unfertilized with 297.67 g and 283.78 g which is in accordance with the result of the study of Jan and Amanullah (2002). Review of earlier studies in corn revealed that 1000 seed weight is the most significant yield characteristic that reveals the yield potential. Yadav and Singh (2000), Ramachandrappa *et al*., (2004), Sahoo and Mahapatra (2004), and Durga *et al*., (2012) described that wider plant spacing and higher NPK application treatments have ensued in significantly higher weight.

Shelling Percentage (%)

Shelling percentage of glutinous corn was significantly affected by the main plot (PD) and sublot (FR) and their interaction (Table 4). Result shows that the combination of PD (MDR) and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained a higher percentage of shelling recovery of 93.23% than wider PD 75 cm x 20 cm regardless of the level of FR applied ranging from 74.37% - 79.65% (Figure 2). The result is not in accordance with the study of Selassie (2015) who that reported N fertilizer rates and planting density did not have significant effect on the shelling percentage of corn because he justified that as N fertilizer rate was increased, both the grain and cob weight increased in equivalent proportions, which kept the shelling percentage constant in all the.

Table 4: Yield performance (Shelling percentage, seed size and estimated yield) of glutinous corn planted in different planting distances applied with different recommended fertilizer rate

TREATMENTS	1000 SEED WEIGHT (g)		SHELLING PERCENTAGE (%)		YIELD (tha^{-1})	
PLANTING DISTANCE (PD)	*		**		Ns	
75 cm x 20 cm	305.33 a		76.46 c		4.33	
60 cm x 20 cm	297.00 b		80.09 b		4.13	
80:30 cm x 20 cm	304.25 a		86.95 a		4.73	

FERTILIZER RATE (FR)	**		**		**	
0-0-0 (control)	283.78 c		78.63 c		2.59 d	
120-60-60	297.67 b		79.75 c		3.85 c	
180-80-80	309.44 a		81.85 b		5.13 b	
200-100-100	317.89 a		84.43 a		6.02 a	
PD X FR	ns		**		*	
CV (a) % CV (b) %	1.29 2.85		3.85 2.60		9.20 6.68	
Means marked with the same letter in a column are not significantly different using $HSD_{0.05}$						
*	= significant at 5%					
**	= significant at 1% level					
ns	= not significant					
cv	= Coefficient of variance					

Treatments However, Durga *et al.*, (2012) defined shelling percentage as another parameter which gives an indication about seed yield and a postharvest attribute. They described that it is less influenced directly by management practices like plant spacing and fertilizer rate. Although, superior performance of treatment combination for other yield components like number of ear length, ear diameter, and 1000 seed weight would result in higher shelling percentage due to heavier seed weight in contrast to the weight of the stem.

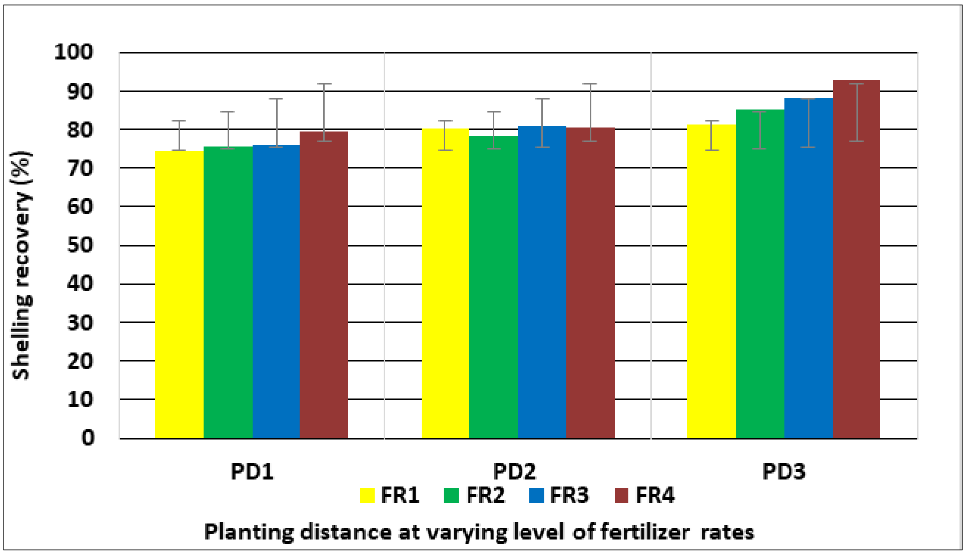

Figure 2: Interaction effect between planting distance and fertilizer rate on the shelling recovery (%) of glutinous corn

Grain Yield (tha^{-1})

ANOVA shows that both the main plot, sublot and their interaction significantly affected the yield of glutinous corn (Table 4). There was an increased in yield as the fertilizer rate increases regardless of the PD. However, interaction effect (Figure 3) between FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} and PD – MDR gave the highest yield with 6.93 t ha^{-1} than 75 cm x 20 cm (5.72 t ha^{-1}) and 60 cm x 20 cm (5.42 t ha^{-1}). Conversely, unfertilized plots regardless of PD obtained the lowest grain yield ranging from 2.25 – 2.80 t ha^{-1} which is expected because the corn planted were depend solely on the natural soil fertility in the experimental area used. This result proves that high planting density and N fertilizer were beneficial for optimum yield when all other conditions are favorable to attain the highest grain yield in corn. These results are in conformity with Imran *et al.*, (2015) and Bozorgi *et al.*, (2011) also reported that highest corn grain yield was obtained from the combination of highest planting density with highest in N fertilizer level followed by PD2 applied with FR2 (78.39%) and PD1 applied with FR4 (79.65%). Previous researches reported that yield components, such as ear length and diameter, and ear weight were identified as key components to improve corn yield (Yadav and Singh, 2000). Further, Durga *et al.*, (2012) corroborated that effect of plant spacing, fertilizer rates and their interaction were highly significant in regulating the seed yield per plant of corn.

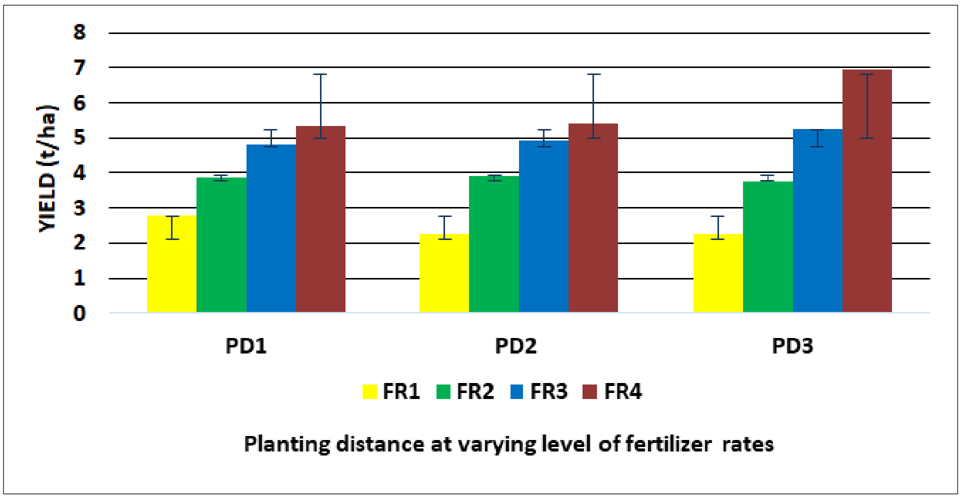

Figure 3: Interaction effect between planting distance and fertilizer rate on the estimated yield performance (tons per hectare) of MMSU glut 1 corn

Agronomic Nutrient use Efficiency

ANOVA revealed that PD and FR significantly affected the fertilizer use efficiency (FUE) of glutinous corn but not of their interaction (Table 5). Results indicate that FUE was increasing as spacing of glutinous corn getting closer. Accordingly, PD MDR obtained the highest FEU (16.20% (N) and 32.29% (P and K) which was higher by 32.0% (N) and 31.99% (P and K) compared to the control PD 75 cm x 20 cm with only 12.27% (N) and 24.54% (P and K) use efficiencies. However, PD 60 cm x 20 cm was comparable with MDR and higher by 20.79% N and 26.24% P and K use efficiencies with the control (PD 75 cm x 20 cm).

Similarly, FUE was increasing as fertilizer rates getting higher. Correspondingly, treatments applied with FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained the highest FEU with 17.20% N, and 34.40% P and K use efficiencies. This fertilizer rate obtained a higher NUE by 61.35% and 61.27% by P and K use efficiencies compared to the recommended rate (120 kg $NP_2O_5K_2O$ ha^{-1}). FR 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} was comparable with the highest FR and higher by 51.03% N and 50.87% P and K use efficiencies than the control. However, monitoring of water quality from shallow tubewells which are source for irrigation should be done to avoid groundwater contamination. Studies of Gumtang *et al*., 1999; Robertson and Vitousek, 2009; Sutton *et al*., 2011.

Table 5: Agronomic nutrient use efficiency (Nitrogen, Phosphorous, Potassium) of MMSU Glut 1 corn planted in different planting distances applied with different fertilizer rates

TREATMENTS	AGRONOMIC NUTRIENT USE EFFICIENCY (ANUE)					
	NITROGEN (N)		PHOSPHOROUS (P)		POTASSIUM (K)	
PLANTING DISTANCE (PD)	*		*		*	
75 X 20	12.27	b	24.54	B	24.54	b
60 X 20	15.49	a	30.98	A	30.98	a
80:30 X20	16.20	a	32.39	A	32.39	a
FERTILIZER RATE (FR)	**		**		**	
120-60-60	10.66	b	21.33	B	21.33	b
180-80-80	16.10	a	32.18	A	32.18	a
200-100-100	17.20	a	34.40	A	34.40	a
PD X FR	ns		Ns		Ns	
CV (a) % CV (b) %	22.34 19.37		26.57 25.11		26.57 25.11	
Means marked with the same letter in a column are not significantly different using $HSD_{0.05}$						
*	= significant at 5%					
**	= significant at 1% level					
ns	= not significant					
cv	= Coefficient of variance					

Confirmed that excessive N fertilizer applications can lead to substantial fertilizer N losses through nitrification-denitrification processes which can cause groundwater pollution.

Correlation and Regression Analyses of MMSU Glut 1 Yield to Growth Parameters and Yield components

Table 6 presents the correlations between the yield and different growth parameters and yield components of MMSU Glut as affected by planting distance and fertilizer rate and their interaction. Results show that some parameters are either positively or negatively correlated to others or no relationship at all. Parameters which were highly correlated to yield are plant height at 60, PH_60 ($r = 0.47$, $P < 0.01$) and 90, PH_90 ($r = 0.57$, $P < 0.01$) DAP, ear height, EH ($r = 0.74$, $P < 0.01$), ear weight, EW ($r = 0.75$, $P < 0.01$), ear length, EL ($r = 0.76$, $P < 0.01$), ear diameter, ED ($r = 0.47$, $P < 0.01$), seed size, SS ($r = 0.81$, $P < 0.01$), and shelling percentage, SP ($r = 0.40$, $P < 0.05$). These imply that if the value of each of these parameters will increase it will significantly affect the yield. These means that these parameters greatly influence the yield of MMSU Glut 1.

Kernel row was negatively correlated to yield while stem diameter did not affect significantly the yield of Glut 1. The plant height at 90 DAP and ear height were significantly correlated with the yield components such as EW ($r = 0.60$ and $r = 0.68$, $P < 0.01$), EL ($r = 0.41$ and $r = 0.59$, $P < 0.01$), ED ($r = 0.49$ and $r = 0.63$, $P < 0.01$), and SS ($r = 0.54$ and $r = 0.71$, $P < 0.01$) which eventually affected the yield. Likewise, yield components were highly correlated with each other except or the selling percentage.

The linear regressions between the yield and the different growth and yield parameters of MMSU Glut 1 is presented in Figure 4a. As a result, SS or weight of 1000 seeds is the most predictable parameter in this study. The prediction power indicates that 66% of the yield of MMSU Glut1 is explained by SS. This implies that only 36% of the variance of the yield is not explained by the SS. EH is a growth parameter that explains about 55% of the yield of MMSU Glut1. This means that this parameter was not able to explain 45% of the yield of MMSU Glut 1.

As for EW, observations show that this parameter strongly influences SS, with a regression coefficient of 0.58 as shown in Figure 4b. This prediction power of the SS is associated with those of SD and EL. These observations imply that improving the performance of these parameters is an effective way to increase the SS and ultimately the yield of MMSU Glut 1.

Table 6: Linear Correlations (Pearson coefficients) between yield (YLD) and growth parameters and yield components of MMSU Glut 1

	YLD	PH_60	PH_90	EH	EW	EL	ED	SS	SP	KR
PH_60	0.470**									
PH_90	0.574**	0.654**								
EH	0.740**	0.603**	0.814**							
EW	0.754**	0.278 ns	0.600**	0.677**						
EL	0.759**	0.275 ns	0.409*	0.586**	0.846**					
ED	0.780**	0.295 ns	0.488**	0.634**	0.764**	0.780**				
SS	0.811**	0.305 ns	0.537**	0.711**	0.760**	0.745**	0.746**			
SP	0.396*	0.121 ns	0.089 ns	0.174 ns	-0.077 ns	0.043 ns	0.233 ns	0.180 ns		
KR	-0.004ns	0.176 ns	0.065 ns	0.036 ns	0.009 ns	0.023 ns	0.023 ns	-0.071 ns	-0092 ns	
SD	0.272ns	0.227 ns	0.222 ns	0.243 ns	0.432*	0.321 ns	0.33*	0.347*	0.439**	0.343*

Note : ns = not significant; * = significant; ** = highly significant; plant height at 60 (PH_60) and 90 (PH_90) DAP; ear height (EH), ear weight (EW), ear length (EL), ear diameter (ED), seed size (SS), shelling percentage (SP).Kernel Row KR), and stem diameter (SD)

Economic Analysis of Corn Grain Yield as Influenced by PD and FR

The economic analysis provides the best combinations of PD and FR treatments that give the highest benefits (Table 7). Specifically, the computation of total variable cost (TVC), net benefit analysis, and return above variable cost (RAVC) reveal that the best economical treatment combination was the PD – MDR and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} which gave the highest net income of PhP 86,075.00 ha^{-1} with a RAVC of 1.17. Although, it has the highest total cost of production at PhP 73,315.00 ha^{-1}, this was compensated by the high grain yield attained with 6.93 t ha^{-1} giving the highest gross income of Php 159,390.00 ha^{-1} if priced at Php 23.00 kg^{-1}. The farmers practiced FR 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} and PD 75 cm x 20 cm gave a yield of 3.87 t ha^{-1} which is higher by 6.90% and 4.13% than the provincial (3.62 t ha^{-1}) and regional average yield, respectively. Increasing the fertilizer rates to 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} and 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} with the same PD would give a yield advantage of 24.03% and 38.24%, respectively. However, with the increased in cost by 8.40% and 16.41%, respectively will not be economically feasible as revealed by their RAVC with 0.76 and 0.90, respectively. Using the PD 60 cm x 20 cm would not be economically feasible regardless of the fertilizer rates that will be used wherein RAVC ranged from 0.08 to 0.73.

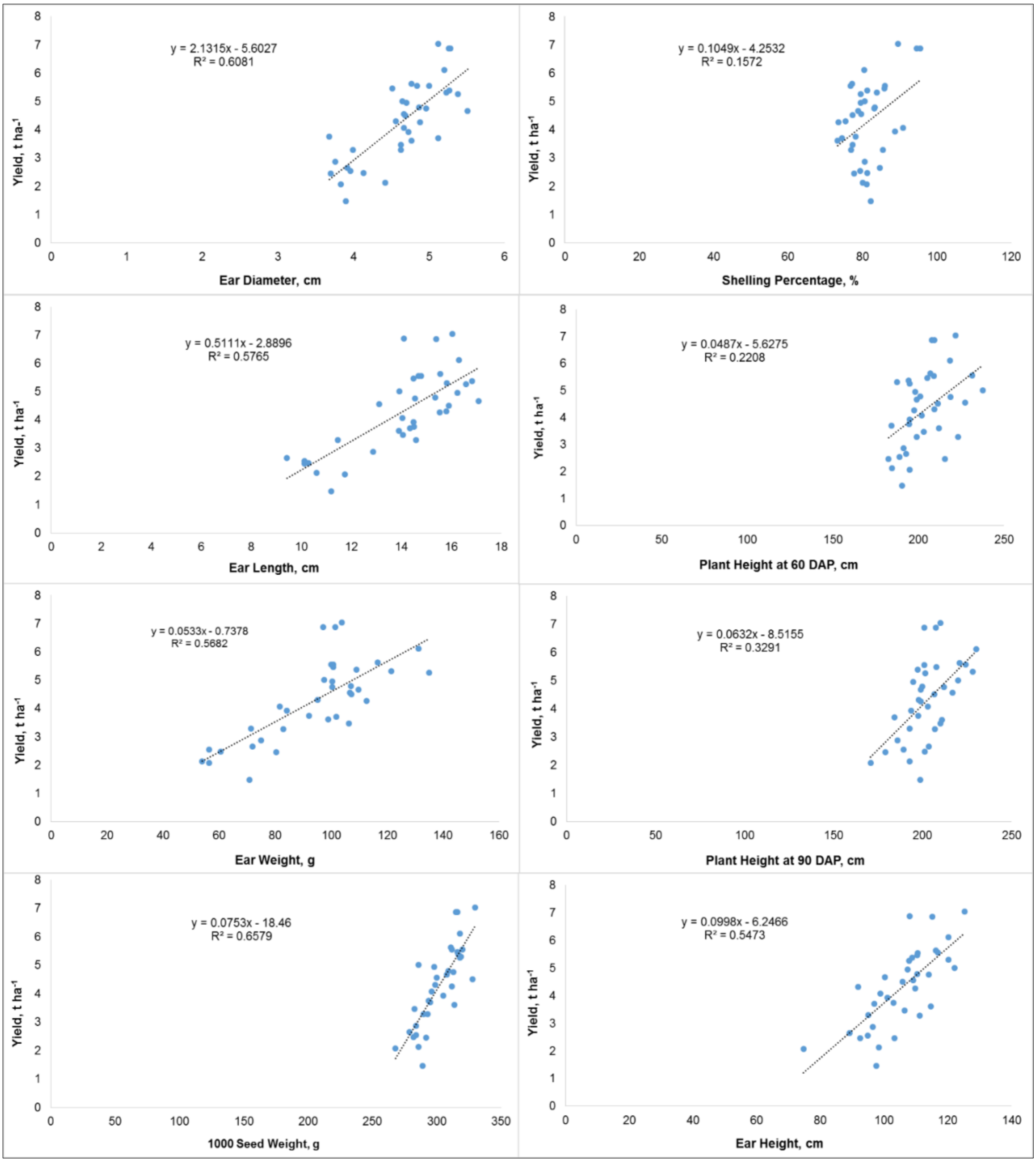

Figure 4a: Linear regression between the yield and other growth and yield parameters

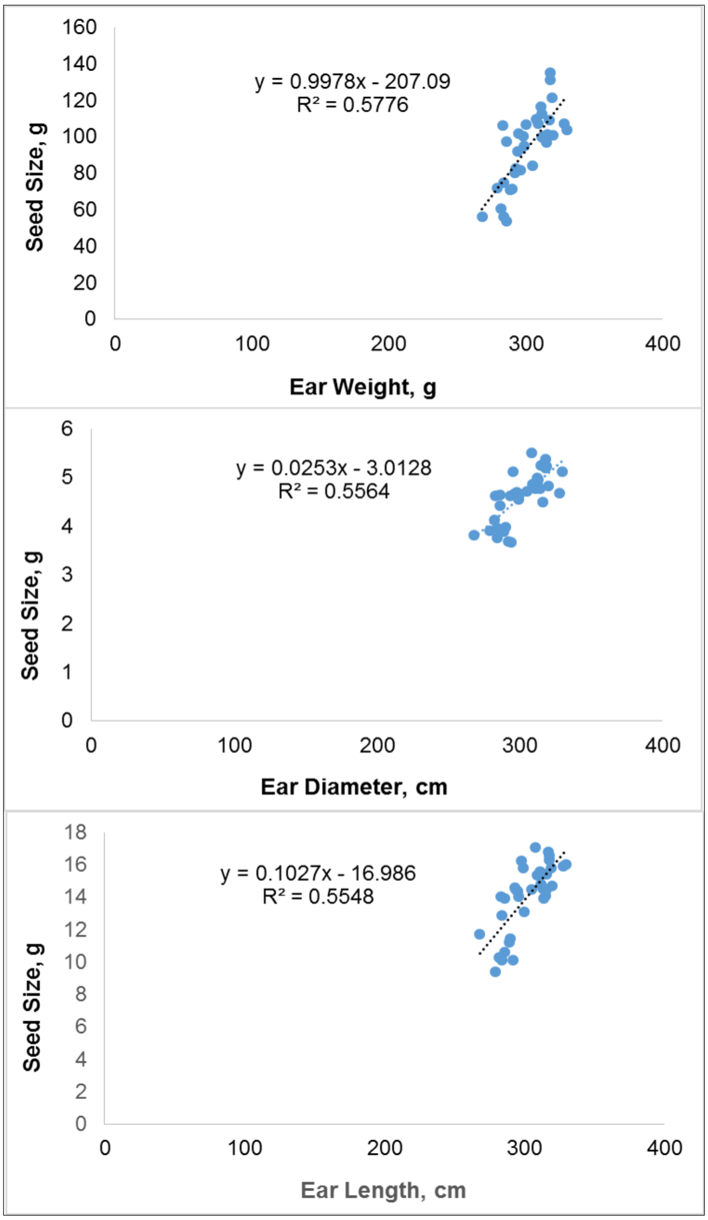

Figure 4b: Linear regression between the seed size and other yield parameters

Table 7: Cost and Return analysis Of MMSU Glut 1 corn under different planting distances and varying level of fertilizer rates

TREATMENTS		Grain Yield	Total Cost of Production	Gross Income	Net Income	Cost of Production (Phpkg^{-1})
PD	**FR**					
PD1	**FR1**	2.80	45,465.00	64,400.00	18,935.00	16.24
	FR2	3.87	59,606.00	89,010.00 89,010.00	29,404.00	15.40
	FR3	4.80	64,618.00	113,620.00 113,620.00	49,002.00	13.08
	FR4	5.35	69,382.00	131,790.00	62,408.00	12.11
PD2	**FR1**	2.25	47,893.00	51,750.00	3,857.00	21.29
	FR2	3.93	62,763.00	90,390.00	27,627.00	15.97
	FR3	4.92	67,703.00	113,160.00	45,475.00	13.76
	FR4	5.41	72,206.00	124,660.00	52,450.00	13.22
PD3	**FR1**	2.27	48,228.00	62,100.00	13,872.00	17.86
	FR2	3.76	62,360.00	86,480.00	24,120.00	16.69
	FR3	5.26	68,011.00	127,490.00	59,409.00	12.28
	FR4	6.93	73,315.00	159,390.00	86,075.00	10.58
*Php 23.00kg^{-1} of grains						

However, a comparative cost and return analysis on the conventional and improved corn production technologies was prepared as shown in Table 8. This aims to determine the difference between the conventional versus the other treatments or improved technologies that performed better than the former which include PD 75 cm x 20 cm in combinations with FRs 160-80-80 and 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}, PD 60 cm x 20 cm with FRs 160-80-80 and 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}, PD 80:30 cm x 20 cm with FRs 160-80-80 and 200-100-100 kg $NP_2O_5K_2O$ $ha^{-1.}$ Results show that all these treatments have a net eturns higher than the conventional practice (75 cm x 20 cm applied with 120-60-60 kg $NP_2O_5K_2O$ ha^{-1}) with PhP 20,390.00; PhP 34,572.00; PhP 16,835.00; PhP 24,315.00; PhP 31,199.00; and PhP 58,971.00. Further, results reveal that PD or MDR 80:30 cmx 20 cm obtained the highest net returns with PhP 58,971.00 followed by the treatment 75 cm by 20 cm applied with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} with PhP 34,572.00. However, though the difference in total cost is only PhP 3,201.00, the net returns was higher by 70.57%. Furthermore, based on the partial budget analysis between the conventional and the best treatment which is the MDR or 80:30 cm x 20 cm applied with 200-100-60 kg $NP_2O_5K_2O$ ha^{-1} revealed that it has net change income of PhP 58,971.00 and a benefit cost ratio of 5.12.

SUMMARY AND CONCLUSION

A lot of NSIC registered glutinous corn varieties have been developed with high yield potentials as high as 8.93 t ha^{-1} (USM Var 22). However, the national average yield only 1.83 t ha^{-1} while Region 1 has 3.71 t ha^{-1} which still far from the yield potential. Therefore, a study was conducted to increase the yield of glutinous corn in Ilocos Norte though modification of planting distance and fertilizer rate. Experimental setups were established for two consecutive dry seasons from 2019-2020 to 2020-2021. The experiments were laid-out in Split-Plot following an RCB Design and replicated three times.

The following are the summary of findings:

1. The availability of N and P in the experimental area was limiting while exchangeable K was adequate.
2. At 90 DAP, corn plants applied with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (211.01 cm). significantly taller than those applied with 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} (202.42 cm) and unfertilized corn plants (190.50 cm) but comparable with those applied with 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} (205.90 cm).
3. Glutinous corn applied with 200-100-100 and 180-60-60 kg kg $NP_2O_5K_2O$ ha^{-1} significantly obtained taller ear height with 113. 64 cm and 111.85 cm, respectively than those applied with the recommended rate (103.68 cm) and no fertilizer (93.61 cm).
4. The ear length, ear diameter, kernel rows, and ear weight of glutinous corn were not affected by planting distance but significant affected by the fertilizer rate.
5. Longer ear length of glutinous corn was obtained when applied with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (15.88 cm) and 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} (15.16 cm).
6. Wider ear diameter of glutinous corn was obtained in plots applied with 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} (5.23 cm).
7. Heavier ear weight was attained from treatment combination of PD 75 cm x 20 cm and FR of 200-100-100 kg $NP_2O_5K_2O$ kg ha^{-1} with 124.36 g but not significantly different with the combination of PD – MDR and FR of 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} with 120.81 g.
8. Larger seed size of glutinous corn was produced based on the weight of 1000 kernels if using planting distance 75 cm x 20 cm (305.33 g) and PD MDR (304.25 g).
9. Increasing the fertilizer rate to 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} and 160-80-80 kg $NP_2O_5K_2O$ ha^{-1} produced a comparable seed size with 317.89 g and 309.44 g, respectively. Giving a size advantage from 6.8% to 12.02% over those applied with the recommended FR (120-60-60 kg $NP_2O_5K_2O$ ha^{-1}) and the unfertilized treatment.
10. Shelling percentage of glutinous corn was significantly affected by planting distance and fertilizer rate and their interaction. Combination of PD (MDR) and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained a higher shelling percentage of 93.23% than wider PD 75 cm x 20 cm regardless of the level of FR applied ranging from 74.37% - 79.65%.
11. Combination of PD MDR (80:30 cm x 20 cm) and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} gave the highest yield with 6.93 t ha^{-1} than 75 cm x 20 cm (5.72 t ha^{-1}) and 60 cm x 20 cm (5.42 t ha^{-1}), and the recommended fertilizer rate, 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} and Planting distance, 75 cm x 20 cm with only 3.87 t ha^{-1}.
12. PD and FR significantly affected the fertilizer use efficiency (FUE) of glutinous corn. FUE was increased as spacing of glutinous corn getting closer. PD MDR obtained the highest FEU which was higher by 32.0% (N) and 31.99% (P and K) compared to the control PD 75 cm x 20 cm with only 12.27% (N) and 24.54% (P and K) use efficiencies. However, PD 60 cm x 20 cm was comparable with MDR and higher by 20.79% N and 26.24% P and K use efficiencies with the control (PD 75 cm x 20 cm).
13. FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} obtained the highest FEU with 17.20% N, and 34.40% P and K use efficiencies.

Based on the summary of findings, following conclusions were drawn:

1. Planting distance alone did not affect the growth and yield performance of the glutinous corn except seed size and shelling percentage.
2. Fertilizer rates influenced the growth and yield parameters of glutinous corn except stem diameter. Application of FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} provided glutinous corn gave a yield increase of 17.5% (PD 75 cm x 20 cm) , 55% (PD 60 cm x 20 cm) and 105% ((PD 80:30 cm x 20 cm) over FR 180-80-80 kg $NP_2O_5K_2O$ ha^{-1}, FR 120-60-60 kg $NP_2O_5K_2O$ ha^{-1}, and the unfertilized, respectively.
3. The treatment combination of PD MDR and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} gave glutinous corn the highest yield with 6.93 t ha^{-1} which was higher by 28.10% using the combination of PD 60 cm x 20 cm and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} and 29.53% using combination of PD 75 cm x 20 cm and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1}, and 79.07% higher than the recommended practice FR 120-60-60 kg $NP_2O_5K_2O$ ha^{-1} and PD 75 cm x 20 cm.
4. Using the combination PD MDR and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} gave the glutinous corn the highest net profit ha^{-1} of PhP 86,075.00 and lowest production cost kg^{-1} seeds. However, as compared to the conventional practices, it has a net return of PhP 58, 971.00 and a benefit-cost ratio of 5.76.

RECOMMENDATIONS

Based on the conclusions made, the researchers recommend the following:

1. Use of the combination of MDR 80:30 cm x 20 cm and FR 200-100-100 kg $NP_2O_5K_2O$ ha^{-1} can be used as a new strategy in increasing the yield of glutinous corn.
2. Inclusion of inoculant (Bio-N for corn) and organic fertilizer should be tested to lessen the amount of Nitrogen fertilizer and reduce the production cost while improving the soil fertility.
3. Validation trial of the developed packaged of technology should be done in wider plots for a more conclusive result.

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