Philippine e-Journal for Applied Research and Development *12(2022), 23-31* ISSN 2449-3694 (Online)
https://pejard2.slu.edu.ph/wp-content/uploads/2022.05.23.pdf

Effect of agro-climatic factors on the yield of corn (IPB Var 6) under rainfed conditions in the Philippines

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Received, 07 December 2021; Accepted, 21 March 2022; Published, 23 May 2022

Abstract

The study aimed to determine the productivity of IPB Var 6 across different growing locations and identify the climatic factors affecting corn yield in the three climatic types based on Corona's classification. Field experiments were conducted for one cropping season in selected corn-growing areas in Luzon, Visayas and Mindanao. These were laid out in a randomized complete block design (RCBD) with two replicates for each location. Climatic parameters such as temperature, rainfall, and relative humidity were determined in each location. Across locations, IPB Var 6 had the highest grain yield in Palayan, Nueva Ecija with a Type I climate; Tagbina, Surigao del Sur with a Type II climate; and Pitogo, Quezon with a Type IV climate. Temperature affected the grain yield of IPB Var 6 across climatic types in Luzon, Visayas, and Mindanao under a Type I climate. At the same time, location (environment) was also a factor under Type II and Type IV climates. The findings are useful in planning strategies like the dissemination of climatic information and the adjustment of cropping calendars in specific planting locations.

Key words: Corn productivity, temperature, rainfall, humidity, environment

Introduction

Corn is the most important cereal crop in the Philippines. It is grown for food, livestock feed, and as raw materials for many industrial products (Verheye, 2010). It is a staple food for 20% of the Filipino population, particularly in the southern regions of Visayas and Mindanao (Ocampo and Cotter, 2012). Like for any other crop, corn production is influenced by environmental conditions at important stages of plant development. Climatic conditions, including rainfall, temperature, and humidity, significantly impact on corn yield (Ozkan and Akcaoz, 2002). Under rainfed conditions, which characterizes corn farming in the Philippines, corn crop yield is influenced by extreme climate variables such as maximum and minimum temperature, maximum and minimum relative humidity, rainfall, sunshine hours, and potential evapotranspiration (Adamgbe & Ujoh, 2013).

Omoyo et al. (2015) noted that rising temperatures and low relative humidity, which promote field crop evapotranspiration, and the associated changes in inter-season rainfall, impact corn seed germination, grain filling, and growing season length. The higher the temperature, the lower the corn yield, and the lower the temperature, the greater the yield (Oke, 2016). This iterates earlier findings showing that corn yield declines with increased temperature (Joshi et al., 2011). In addition, Mijinyawa and Akpenpuun (2015) observed that an increase in maximum temperature, minimum temperature, relative humidity, and sunshine hours will increase the yield of all crops except for corn, where an increase in maximum temperature will cause a decrease in yield. However, it has also been observed that even with an increase in temperature, increase on corn yield was still possible due to significant amount of rain received. This shows that the correct amount of rain and distribution pattern can reduce the impact of temperature on maize yield (Cudjoe et al., 2021).

The amount of rainfall is a very important variable that has a big impact on corn yield (Reyes et al., 2009). Corn yield increases when the proper amount of rain falls at the right time. This means that getting the proper amount of rain and in the right pattern is crucial. This supports Rashid and Rassul's (2011) observation that corn crop is completely dependent on rainfall volume and frequency, and its distribution on temporal and spatial scales.

According to Singh et al. (2006), one of the factors limiting corn yields is unpredictability in terms of the start of the rainy season, the amount of rainfall, and its distribution during the corn growing season. It is not just the lack of water that can be problematic but also its excess. Cudjoe et al. (2021) has observed that when rainfall is above normal, it creates waterlogging, which has an impact on corn productivity. Corn requires a set amount of water, and an increase in rain increases yield up to a certain point, after which grain yield declines (Magehema et al., 2014; Rashid and Rasul, 2011).

In the Philippines, a corn variety called IPB Var 6 has been developed by the Institute of Plant Breeding (IPB) of the University of the Philippines Los Baños. Chiefly designed to be processed into corn grits for human consumption, this is a high-quality protein corn variety that contains more protein and the essential amino acids lysine and tryptophan than other corn varieties and white rice (UPLB, 2018). As this variety has just been introduced to corn farmers, no studies have yet been conducted on how its productivity is affected by climatic conditions obtaining in the various corn-growing areas all over the country.

The goal of this study is to determine the productivity of IPB Var 6 and the factors limiting its yield in different conditions in the Philippines. In particular, it aims to determine the productivity of IPB Var 6 across different growing locations and to identify the major climatic factors affecting corn yields in the three climatic types based on Corona's classification. Specifically, these agro-climatic factors are temperature, rainfall, and relative humidity. In addition, location (environment) will also be assessed, which is a combination of all agro-climatic factors. By evaluating the responses of IPB Var 6 to agro-climatic factors across different environments, the study can provide appropriate information to corn farmers that will enhance their capacity to adapt to variability in climatic conditions.

Materials and Methods

Time and Place of Study

Field experiments were conducted in selected corn-growing areas in Luzon, Visayas, and Mindanao through the Corn-based Farmer-Scientists Training Program (FSTP) based at the Agricultural Systems Institute, College of Agriculture and Food Science (CAFS), University of the Philippines Los Baños (UPLB). The study was conducted using datasets generated from field experiments conducted from 2014 to 2016 during one growing season at 13 experimental sites (Figure 1). In Luzon, four sites under Type IV climate were selected, namely: Maria Aurora, Aurora; Macalelon, Quezon; Pitogo, Quezon; and Unisan, Quezon; while one site, Palayan City Nueva, Ecija falls under Type I climate. In Visayas, Tayasan and Zamboanguita, Negros Oriental fall under Type I, while Danao, Bohol is under Type IV. In Mindanao, Tagbina and Barobo, Surigao del Sur and Bacuag, Surigao del Norte are classified under Type II, while Pinan, Zamboanga del Norte, and Polanco, Zamboanga del Sur are under Type IV.

The cumulative maximum temperature, maximum temperature, mean temperature, rainfall, and relative humidity at the 13 locations are shown in Table 1. The cumulative amount of daily rainfall varied across locations. The average cumulative amount of rainfall across the locations was 478.5mm. Among the environments, Maria Aurora, Aurora had the greatest rainfall (1199.6mm), relative humidity (87.6), and received the lowest minimum and mean temperatures

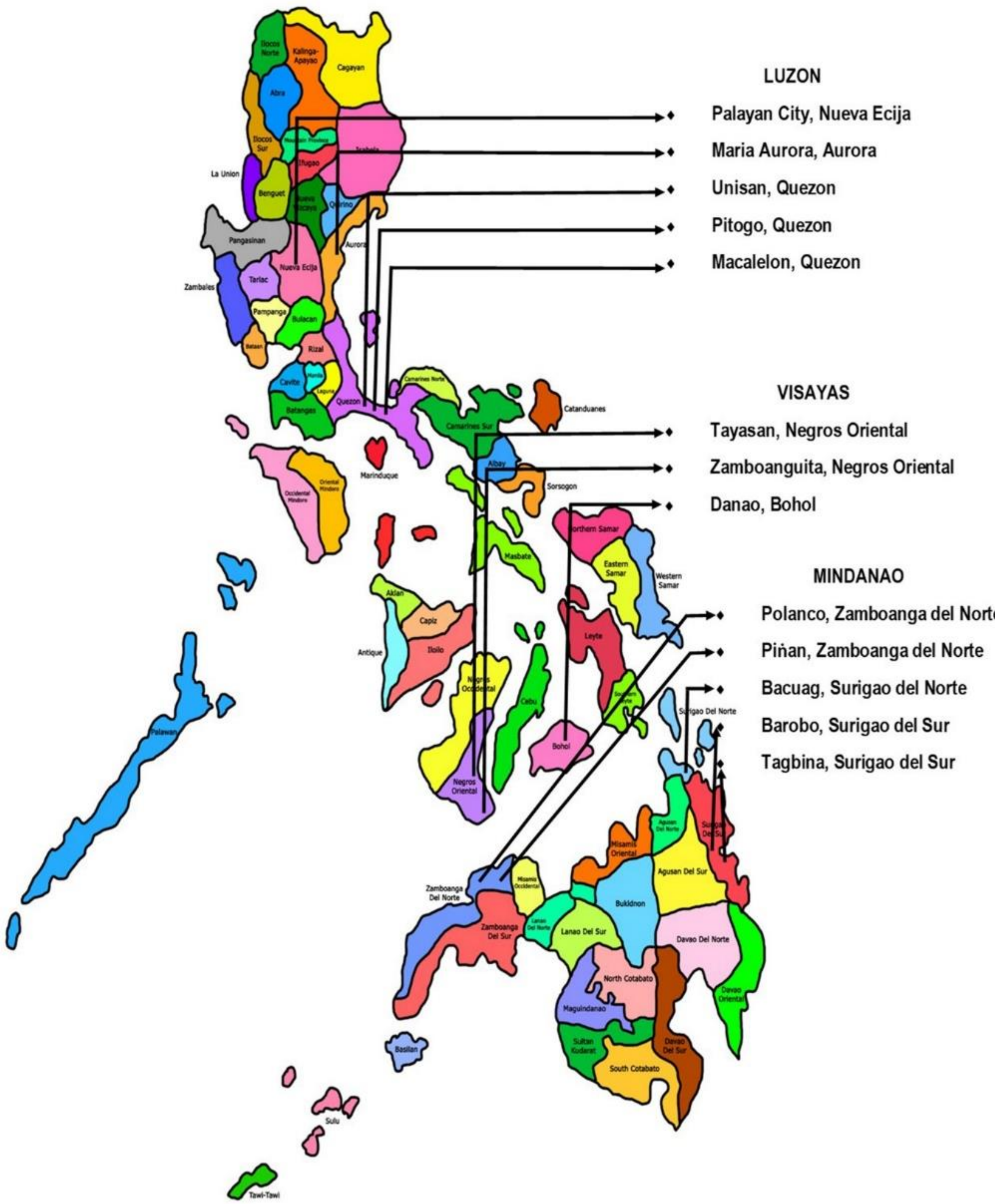

Figure 1. Selected corn growing areas for the study.
(Source of Map: *https://www.cleanpng.com/png-flag-of-the-phippines-vector-map-philippines*)

Table 1. Cumulative amount of climatic variables during the growing season of corn (IPB Var 6) in 13 locations under Type I, II and IV climate.

Climatic Types	Experimental Sites	Rainfall (mm)		Temp. (°c)			RH (%)	
		Range	Total	Tmin	Tmax	Tmean	Range	Mean
I	Palayan City, Nueva Ecija	0-23.4	82.8	22.1	31.7	26.9	58-94	72.6
	Tayasan, Negros Oriental	0-41.0	490.2	24.8	32.4	28.6	68-97	82.5
	Zamboanguita, Negros Oriental	0-41.0	371.7	25.3	32.3	28.8	68-97	82.1
II	Barobo, Surigao del Sur	0-81.9	454.9	24.4	32.6	28.5	74-95	82.2
	Bacuag, Surigao del Norte	0-145	412.1	23.7	33.7	28.7	68-91	79.6
	Tagbina, Surigao del Sur	0-81.9	548.9	24.6	33.5	29.0	72-93	82.6
IV	Maria Aurora, Aurora	0-163	1199.6	20.5	27.9	24.2	75-96	87.6
	Macalelon, Quezon	0-104	498	24.7	33.1	28.9	73-93	84.7
	Unisan, Quezon	0-104	498	24.7	33.1	28.9	73-93	84.7
	Pitogo, Quezon	0-104	498	24.7	33.1	28.9	73-93	84.7
	Danao, Bohol	0-95.6	300.1	24.1	31.2	27.6	79-95	85.1
	Pinan, Zamboanga del Norte	0-19.4	172.6	23.8	32.1	27.9	79-91	83.5
	Polanco, Zamboanga del Norte	0-101.8	694	31.1	42.6	36.8	75-93	82.9

Source: DOST- PAG-ASA (2015).

of 20.5 °C and 24.2 °C, respectively. In contrast, Polanco, Zambonga del Norte, received the highest maximum temperature of 42.6 °C and a mean temperature of 36.8.

Experimental Treatments and Design

A randomized complete block design (RCBD) was used for the field experiments, with two replicates for each location. Each plot had four rows, each with a dimension of 2.25 m x 5 m and a pathway of 1 m in between. IPB Var 6 was obtained from the National Seed Foundation-Institute of Plant Breeding-CAFS, UPLB.

Crop Establishment and Management

The experimental areas were plowed twice at a depth of 30 cm using a manual or tractor-drawn disc plow. Harrowing was completed two weeks after plowing with either a manual or tractor disc harrow. Two seeds were sown per hill at 0.75 m x 0.25 m spacing and thinned to one plant per hill one week after emergence. Each plot has four rows with 20 hills per row. To reduce the border, data was collected only from the two middle rows of each plot. For each location, cultural management practices, including fertilizer application, were based on soil analysis and other location-specific recommendations. Weeds, insect pests, and diseases were controlled as needed.

Date Gathered

Temperature, Relative Humidity and Rainfall

Maximum and minimum temperatures, relative humidity, and rainfall were obtained daily from the Department of Science and Technology-Philippine Atmospheric Administration (DOST-PAG-ASA) weather station nearest to each experimental field. These informations were gathered throughout the growth period of the corn plant, from sowing to harvest.

Grain Yield & Yield Computation

Twenty-four corn ears were harvested at maturity. From these, randomly selected 15 fresh corn ears (5 small, 5 medium, and 5 large) were weighed and used to determine grain yield. Grain yield was calculated in tons per hectare (t ha^{-1}) using the formula (FSTP Manual of Operation, 2009; Anuada et al. 2021):

$$\text{Grain Yield} = \frac{\text{Fresh weight (kg)} \times \text{Number of plants ha}^{-1} \times MC \times SC}{15}$$

Where: number of plants ha^{-1} = 53,333 at 0.75m x 0.25m (1 seed per hill); stand count (SC) ha^{-1} at 80% = 53,333 x 0.80 = 42, 666 plants ha^{-1}; Fresh weight of the sample corn ears (kg) was 5 small, 5 medium, and 5 large; the moisture content (MC) was 15%; and the shelling recovery (SR) was 80%.

Data Analysis

The data gathered was initially checked for normal distribution and homogeneity of variances over the location. The Barlett test was used to check for homogeneity of error variance in the grain yield of IPB Var 6 in Luzon, Visayas, and Mindanao. The grain yield of IPB Var 6 in Luzon, Visayas, and Mindanao and grain yield under various climatic types were described using box plots to show visually the distribution of numerical data and skewness through displaying the data quartiles (or percentiles) and averages. Moreover, the comparison of IPB Var 6 grain yield under various climatic conditions was checked using a T-test. An analysis of variance for IPB Var 6 interaction with growing locations was also done. In addition, a stepwise regression was used to determine the climatic factors such as temperature, rainfall, relative humidity, and location (environments) affecting the grain yield of IPB Var 6 across locations with specific climate types. Data on daily temperature, rainfall, and relative humidity was collected daily from planting to harvesting. Statistical analyses were done using SPSS.

Results and Discussion

Grain Yield of IPB Var 6 in Luzon, Visayas, and Mindanao

The grain yield of IPB Var 6 planted in 13 locations across Luzon, Visayas, and Mindanao is shown in Figure 2. The five locations across

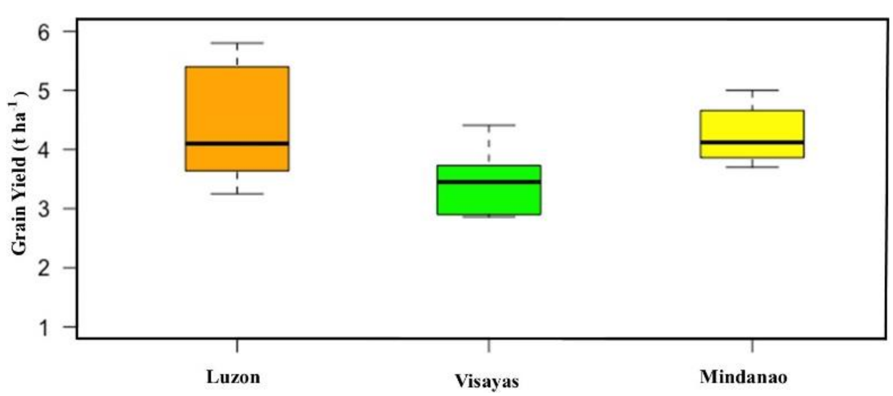

Figure 2. Grain yield of IPB Var 6 in Luzon, Visayas and Mindanao.

Luzon had the highest mean grain yield of 4.4 t ha^{-1} while the three locations in Visayas had the lowest mean grain yield of 3.5 t ha^{-1}. The five locations in Mindanao produced a mean grain yield of 4.2 t ha^{-1} with a minimum grain yield of 3.9 t ha^{-1} and a maximum of 4.5 t ha^{-1}.

IPB Var 6 grain yield under various climatic conditions

For Luzon, Pitogo, Quezon, classified under the Type IV climate, had the highest grain yield of 5.6 t ha^{-1} (Figure 3). IPB Var 6 grown in Type IV climates, such as Macalelon and Unisan, Quezon, and Maria Aurora, Aurora, had a lower yield of 4.0, 3.6, and 3.6 t ha^{-1}, respectively.

On the other hand, IPB Var 6 grown in Palayan City, Nueva Ecija under Type I climate had a yield of 5.2 t ha^{-1}. The grain yield of IPB Var 6 grown in five locations in Mindanao showed that the highest gain yield of 4.8 t ha^{-1} was obtained in Tagbina, Surigao del Sur, which is under a Type II climate. On the other hand, lower grain yields were obtained in the Type IV climate in Pinan and Polanco, Zamboanga del Norte, with 4.5 and 4.0 t ha^{-1}, respectively. IPB Var 6 grown in Tayasan and Zamboanguita, Negros Oriental under Type I climate had a high grain yield of 4.1 t ha^{-1} and 3.3 t ha^{-1}, respectively, as compared to the grain yield of Danao, Bohol under Type IV climate.

The comparison of corn yield (IPB Var 6) using the T-test at different climatic types for Type I and Type II, Type I and Type IV, and Type II and IV are shown in Table 2. There are no significant differences in Type I (M = 4.200, SD =.9539) and Type II (M = 4.233, SD =.4933) with the scores (t = -0.054, p =.960). The magnitude of the means (mean difference =-.0333, 95% CI:-1.7548 to 1.6882) was very small. Type I and Type IV (t = 0.264, p =0.798, and Type II and Type IV (t = -0.605, p =0.562) also showed no significant differences.

IPB Var 6 Interaction with Growing Locations

Several techniques to explain and understand the genotype-by-interaction effect on grain yield variation have been applied. Some of the techniques used to explain the genotype by environment interaction in multiple environment trials involved the characterization of the locations based on environmental variables, direct measurements, computed indices, or through variables derived from crop growth models (Mohammadi et al., 2015).

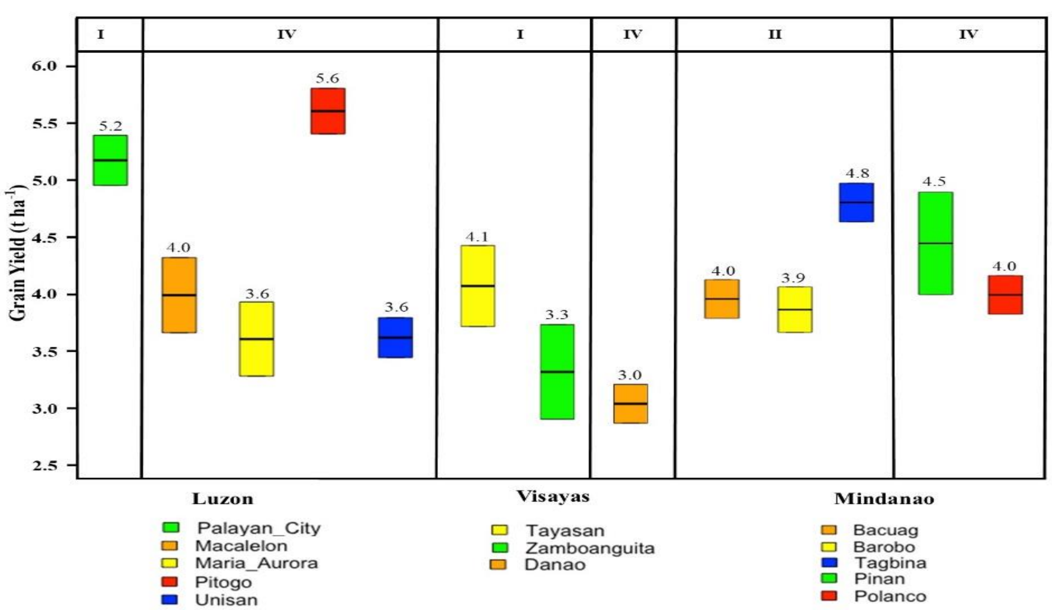

Figure 3. Grain yield of IPB Var 6 under type I, II, and IV climates.

Table 2. Comparison of the corn yield (IPB Var 6) at different climatic type.

		Mean	SD	Levene's Test for Equality of Variances		t-test for Equality of Means						
				F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
											Lower	Upper
Climatic type	I	4.200	.9539	.918	.392	-.054	4	.960	-.0333	.6200	-1.7548	1.6882
	II	4.233	.4933									
Climatic type	I	4.200	.9539	.061	.611	.264	8	.798	.1571	.5945	-1.2137	1.5280
	IV	4.043	.8284									
Climatic type	II	3.733	.3786	.752	.411	-.605	8	.562	-.3095	.5120	-1.4902	.8711
	IV	4.043	.8284									

Analysis of variance for IPB Var 6 across the Philippines showed that the IPB Var 6 planted in different locations was found to have a statistically significant difference at a 5% level of significance (Table 3). The value of F is 7.482, which reaches significance with a p =<.001. Variations in grain yield were observed due to location effects that were clear and the location was established to be diverse.

Climatic Factors Affecting the Grain Yield of IPB Var 6

Table 4 shows the stepwise regression summary for the variables that significantly contributed to the variation in grain yield.

The stepwise regression for grain yield of IPB Var 6 grown across three locations under climate type I showed that temperature in the

Table 3. Analysis of variance for grain yield (IPB Var 6) across locations in Philippines.

Source of Variation	Df	Sum of Squares	Mean of Squares	F	Sig.
Between Groups	12	12.846	1.071	7.482	0.000
Within Groups	13	1.860	0.143		
Total	25	14.706			

**, significant at 1% level, *, significant at 5% level, ^{ns}, not significant

Table 4. Factors affecting grain yield of IPB Var 6 under Type I, II and IV climates.

Climate Type	Variable	R-square	Adj. R-square	C (P)	AIC	RMSE
I	Temperature	0.767	0.709	2.1550	12.4030	0.5053
II	Locations (E)	0.959	0.939	6.4440	-8.7933	0.5039
IV	Locations (E)	0.880	0.778	-3.9690	20.0015	0.3948

E: Environment; C(p): Mallow's CP; AIC: Akaike's Information Criterion; RMSE: Root Mean Square Error corn growing areas had significantly contributed to the variation of IPB Var 6. The variable obtained an R-value of 0.767, which indicates that 76% of the variance within the population can be attributed to temperature as a limiting factor for grain yield of IPB Var 6 under climate Type I in Luzon. These results agree with earlier studies on corn stating that corn yield declined with an increase in temperature, while lower temperature led to greater yield (Oke, 2016; Joshi et al., 2011). In addition, Mijinyawa and Akpenpuun (2015) observed that an increase in maximum temperature, minimum temperature, relative humidity, and sunshine hours would increase the yield of all crops except for corn, where an increase in maximum temperature will cause a decrease in yield.

It was observed that all the agro-climatic factors, such as rainfall, relative humidity, and temperature, have not significantly affected grain yield across corn-growing areas in Type II and Type IV climates. However, location (environment) contributed significantly to the variation of IPB Var 6 when grown under a Type II and Type IV climate. In addition, the result of Type II was that the R-squared value of the location (environment) was 0.959, which means that it explains 95.9% of the variance within the population. This further indicates that location (environment) was a limiting factor for the grain yield of IPB Var 6 under a Type II climate.

Furthermore, it was found out that location (environment) had a significant impact on the variation of IPB Var 6 when grown in seven different locations under a Type IV climate. The R-square value of the environment was 0.880, which explained 88% of the variance within the population. Therefore, the results suggest that only location (environment) is the limiting factor for grain yield under climate Type IV in Mindanao. Anly et al. (2013) observed that the significant effects of environments indicated that testing environments were statistically different in yield potential, that is, the cultivars performed differently across locations. In addition, Fan et al. (2007) found that crop varieties show wide fluctuations in their yielding ability when grown over varied environments or agro-climatic zones. In general, the findings of this analysis are as follows: (1) temperature played a significant role in the grain yield variation of IPB Var 6 under the Type I climate, and (2) no specific climatic factors played a significant role in the variation in grain yield of IPB Var 6 under the Type II and IV climates. However, the combination of all agro-climatic factors (environment) has affected grain yield.

Conclusion

IPB Var 6 was planted across 13 locations in Luzon, Visayas, and Mindanao in order to determine its productivity in the different growing locations and at the same time identify the climatic factors affecting corn yield in the three climatic types. The highest grain yields in Luzon were recorded in Pitogo, Quezon under Type IV climate (5.6 t ha^{-1}) and in Palayan City, Nueva Ecija, with a Type I climate (5.2 t ha^{-1}). In Visayas, Tayasan, Negros Oriental produced higher grain yield (4.1 t ha^{-1}) than Danao, Bohol (3.03 t ha^{-1}) under the Type IV climate. In Mindanao, the highest grain yields (4.8 t ha^{-1}) were obtained in Tagbina, Surigao del Sur with a Type II climate and in Piñan, Zamboanga del Norte with a Type IV climate (4.5 t ha^{-1}). Grain yields were relatively higher in the Type IV climate across Luzon, Visayas, and Mindanao. Of the various climatic factors, temperature affected the grain yield of IPB Var 6 across climatic types in Luzon, Visayas, and Mindanao under a Type I climate. At the same time, location (environment) was also a factor under Type II and Type IV climates. These findings are relevant in planning appropriate interventions like the dissemination of climate information and the adjustment of cropping calendars in specific planting locations. Further studies may also consider the elevation of the area, terrain, and the response of different soil types as additional variables.

Acknowledgments

I would like to thank the Farmer-Scientists Training Program (FSTP), which is co-funded by the Agricultural Training Institute and is led by Romulo G. Davide, Program Leader & Professor Emeritus at UPLB. I would also like to thank the PAGASA-DOST Climate Section for providing the data on weather parameters at various agrometeorological stations, as well as the FSTP staff, Municipal Agriculturists, Agricultural Technologists, and Farmer-Scientists for their active participation in the program.

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