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Relationships between climatic variables and corn yield of IPB Var 6 under selected rainfed conditions in the Philippines

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ABSTRACT

Field studies were carried out in selected rainfed conditions in the Philippines for one cropping season. The study determined the corn yield of IPB Var 6 in various locations and investigated the relationship between the corn yield of IPB Var 6 and climate variables such as relative humidity, rainfall, and temperature. Data on climatic variables was collected by the PAGASA-DOST Climate Section from various agrometeorological stations near the experimental sites. A randomized complete block design was used for the experiments, with two replications for each location. The relationship between climatic variables and corn yield was determined using correlation analysis. In the study, it was found that corn yield has a positive correlation with precipitation. Corn yield had a negative correlation with the minimum, maximum, and mean temperatures, as well as relative humidity. Among 13 locations, IPB Var 6 planted in Pitogo, Quezon, produced the highest grain yield. The findings can be used to plan suitable adaptation strategies for farmers to use in corn production, suitable crops to suit the prevailing conditions and the adjustment of the cropping calendar due to changes in rainfall patterns.

INTRODUCTION

Climate unpredictability has significant negative influences on natural and human systems, and it will affect food security through its impacts on all components of global, national, and local food systems (FAO, 2012). The major challenges that farmers encounter are climatic variability and diseases and pests. Since most corn-producing locations are rainfed, a good cropping season is totally dependent on rain (Reyes et al., 2009).

In addition, the corn plant needs 4 to 5 mm of water per day. The requirement can be as high as 6 to 8 mm/day throughout crucial phases such as silking and soft dough. If the plant does not get enough water throughout this time, up to 50% of the yield may be lost (Reyes et al., 2009). According to Lansigan et al. (2007), the most crucial point is around 55 days after planting. In addition, water is necessary 40 days after planting at the beginning of the flowering initiation to the reproductive stage. Furthermore, corn also thrives in areas with moderate to high rainfall, deep, well-drained soils, and higher water retention capacity (Smith, 2006; Masere and Duffy, 2014).

Corn is mostly grown in the Philippines without irrigation and is rainfed or varies depending on the normal rainy season, especially during the critical pollination stages (Anuada et al., 2021). Climate variability factors such as maximum and minimum temperatures, maximum and minimum relative humidity, rainfall, sunshine hours, and probable evapotranspiration have also been shown to have a significant impact on crop production in non-irrigated areas (Adamgbe and Ujoh, 2013). According to Befekadu and Berhanu (2000), rainfall is the most significant climatic variable that influences corn development and growth. Rainfall also supplies water, which is used as a channel for the uptake of nutrients. Because of this critical role, a water shortage has a negative effect on phenological plant development, resulting in poor productivity (Ndami and Watanabe, 2015). Rainfall patterns and the amount received determine crop success or failure under rainfed conditions. As a result, rainfall amounts as well as seasonal patterns are crucial to obtaining a comprehensive understanding of both the biotic and abiotic environments. Rainfall patterns have been crucial for optimizing agricultural enterprise distribution as well as adaptability (Monadjem and Perrin, 2003).

Because the majority of the country's agricultural systems are rainfed, dry spells during the growing season have a significant impact on yield and productivity. According to Adamgbe and Ujoh (2013), agricultural production in most of the world's tropics and equatorial regions, as well as across large areas outside the tropics, has been determined primarily by the amount of rainfall received and stored by soil, rather than surface temperature. Air humidity influences the quantity of water transpired by plants, with much less matter obtained in a dry climate environment (Parry et al., 1990). According to Mugalavai and Kipkorir (2013), dry spells have the biggest influence on rainfed crops such as corn during crucial stages of plant development, including flower initiation and grain filling.

Rainfall, temperature, ultraviolet radiation, as well as carbon dioxide (CO_2) levels will have the greatest effect on agriculture. Long-term shifts in seasonal climatic patterns, as well as increases in the intensity and frequency of climate change, have caused agricultural disruption. Variation in rainfall patterns has been found to have a significant impact on crop yields (Nyong, 2008).

Other factors include field activities such as soil, timing of planting, pests, diseases, and climate. The most significant climatic elements in agricultural production are temperature, rainfall, and potential evaporation (Ayoade, 2004). In a tropical environment, however, rainfall has a greater influence on inter-annual changes in agricultural produce because it determines the supply of water to plants (Adejuwon, 2010). Furthermore, rainfall has been the most limiting climatic factor in crop development and yield because crops are particularly sensitive to water deficits (Falkenmark, 1989). Moreover, "in developing countries in which agricultural production is mostly rainfed, rainfall is the greatest attribute of all climatic factors determining the growing season. It was also discovered that the amount of rainfall has the potential to significantly impact agricultural production" (Nyong, 2008). IPB Var 6 was also chosen for the study because it is intended to be processed into corn grits for human consumption. IPB Var 6, a high-quality protein corn, was developed by the Institute of Plant Breeding (IPB)-University of the Philippines Los Banos (UPLB, 2018). The ability of corn producers to adjust to climatic variability can be improved by evaluating corn yield (IPB Var 6) response to climatic variables. The objective of this study was to determine the corn yield of IPB Var 6 in different locations as well as the relationship between climatic variables and corn yield, with a focus on rainfall, temperature, and relative humidity.

MATERIALS AND METHODS

The field experiments were conducted in selected rainfed conditions in the Philippines, as shown in Figure 1, by 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 Baňos (UPLB). The study was conducted using datasets generated from field experiments conducted in 13 experimental sites from 2014 to 2016 during one growing season, and the dates of establishment in experimental sites, such as planting and harvesting, are listed in Table 1.

A randomized complete block design was used for the experiments, with two replications for each location. Each plot consists of four rows, each with a 2.25 m × 5 m dimension and a 1 m pathway between them. The National Seed Foundation-IPB, CAFS, UPLB was the source of IPB Var 6.

The experimental locations have been plowed twice at a depth of at least 30 cm using a manual or tractor-drawn disc plow. The harrowing was done two weeks after plowing with either a manual or tractor disc harrow, if available in the area. Two seeds were sown at 75 cm × 25 cm spacing per hill, and one plant per hill was thinned one week after emergence. Each plot has four rows of 20 hills each. To reduce border effects, data is collected primarily from the two middle rows of each plot. Soil analysis is used to make recommendations for fertilizer management practices in each specific location. Unwanted plants, insects, and disease pests were eradicated as needed.

The 24 corn ears were harvested when they reached maturity. A total of fifteen fresh corn ears (5 small, 5 medium, and 5 large) were chosen at random and weighed to determine grain yield. To calculate grain yield in tons per hectare (t ha^{-1}), use the formula below (FSTP Manual of Operation, 2009; Anuada et al., 2021).

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

Where: Number of plants ha^{-1} = 53,333 at 0.75 m × 0.25 m (1 seed per hill); stand count (SC) ha^{-1} at 80% = 53,333 × 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%.

Maximum and minimum temperatures, relativehumidity, and rainfall were measured daily at weather stations maintained by the Department of Science and Technology-Philippine Atmospheric Administration (DOST-PAG-ASA) near each experimental field. This information was gathered throughout the growing season

Figure 1. Map of the selected corn-growing areas for the study.

Table 1. Planting and harvesting dates of the experimental trials at selected rainfed condition in the Philippines.

Locations	Date of planting	Date of harvesting
Palayan City, Nueva Ecija	Nov. 18, 2014	March 3, 2015
Maria Aurora, Aurora	Nov. 20, 2014	March 5, 2015
Unisan, Quezon	May 28, 2015	Sept. 10, 2015
Pitogo, Quezon	May 25, 2015	Sept. 9, 2015
Macalelon, Quezon	May 27, 2015	Sept. 9, 2015
Tayasan, Negros Oriental	July 2, 2015	Oct. 15, 2015
Zamboanguita, Negros Oriental	Aug. 4, 2015	Nov. 17, 2015
Danao, Bohol	Oct. 23, 2015	Feb. 15, 2016
Polanco, Zamboanga del Norte	July 1, 2015	Oct. 14, 2015
Piṅan, Zamboanga del Norte	Nov. 15, 2015	Feb. 28, 2016
Bacaug, Surigao del Norte	May 5, 2015	Aug. 18, 2015
Barobo, Surigao del Sur	May 7, 2015	Aug. 20, 2015
Tagbina, Surigao del Sur	July 1, 2015	Nov. 14, 2015

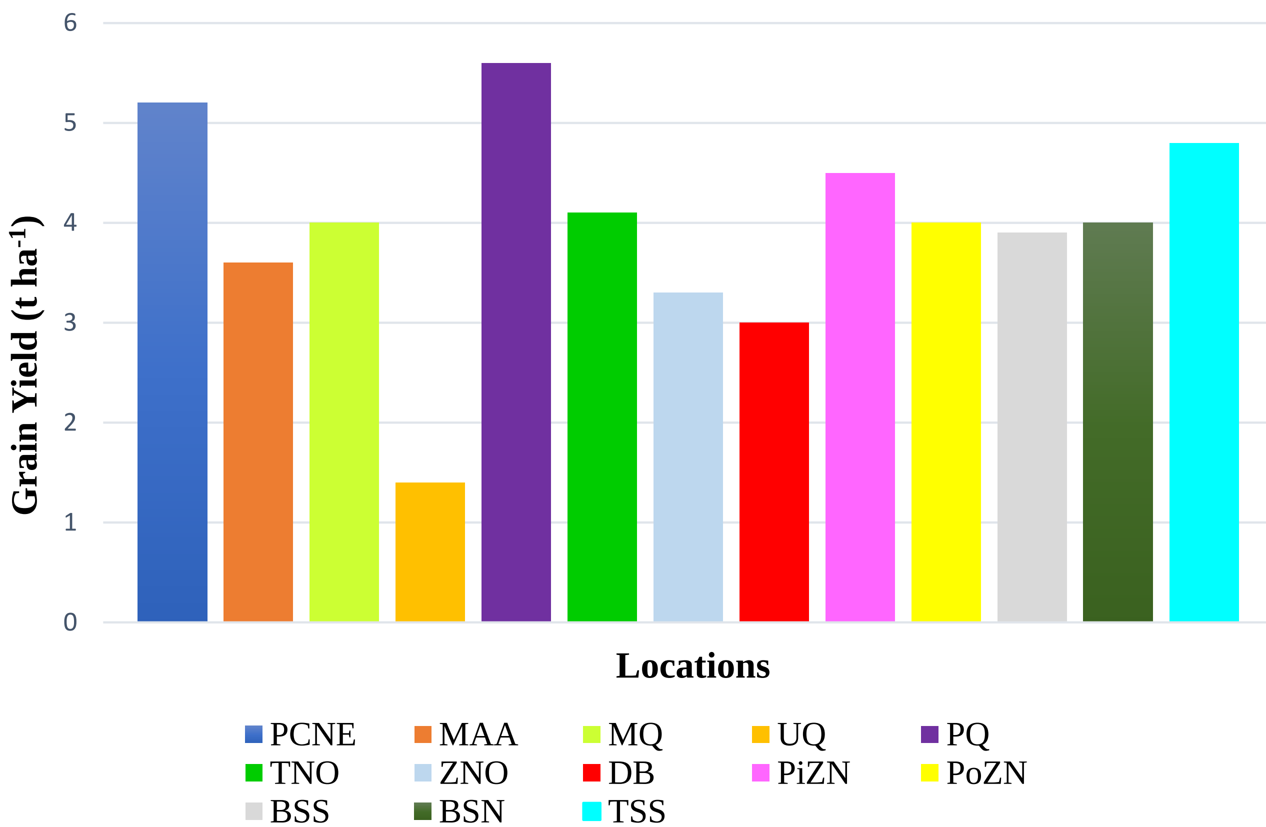

Figure 2. Grain yield of IPB Var 6 across different locations in the Philippines. Locations: **PCNE,** Palayan City, Nueva Ecija; **MAA,** Maria Aurora, Aurora; **MQ,** Macalelon, Quezon; **UQ,** Unisan, Quezon; **PQ,** Pitogo, Quezon; **TNO,** Tayasan, Negros Oriental; **ZNO,** Zamboanguita, Negros Oriental; **DB,** Danao, Bohol; **PZN,** Pinan, Zamboanga del Norte; **PoZN,** Polanco, Zamboanga del Norte; **BSS,** Barobo, Surigao del Sur; **BSN,** Bacuag, Surigao del Norte; **TSS,** Tagbina, Surigao del Sur.

of the corn plant, from sowing to harvest. Initially, the obtained data was checked for normal distribution and variance homogeneity across locations. SPSS V. 25 was used for statistical analysis. Correlation analysis was used to determine the relationship between climatic variables and corn yield. In addition, a correlation matrix for climatic variables was also obtained.

RESULTS AND DISCUSSION

The grain yield of IPB Var 6 planted in 13 selected rainfed conditions in the Philippines was shown in Figure 2. The Barlett test was used to analyze the homogeneity of error variance in grain yield from various locations. Based on the result, it appears that the *p*-value is higher than 0.05.

Among the 13 selected rainfed locations in the Philippines (Palayan City, Nueva Ecija; Maria Aurora, Aurora; Macalelon, Unisan, and Pitogo, Quezon; Tayasan and Zamboanguita, Negros Oriental; Piňan and Polanco, Zamboanga del Norte; Bacuag, Surigao del Norte; Barobo and Tagbina, Surigao del Sur). The grain yield ranking varied across the 13 locations. With a grain yield of 5.6 t ha^{-1}, IPB Var 6 planted in Pitogo, Quezon has the highest grain yield. However, IPB Var 6 grown in Palayan City, Nueva Ecija had the next higher yield of 5.2 t ha^{-1}. Tagbina, Surigao del Sur, on the other hand, had a higher grain yield of 4.8 t ha^{-1} as compared to other locations in Pinan, Zamboanga del Norte; Tayasan, Negros Oriental; Macalelon, Quezon; Polanco, Zamboanga del Norte; Bacuag, Surigao del Norte; Barobo, Surigao del Sur; Ma. Aurora, Aurora; Zamboanguita, Negros Oriental; and Danao, Bohol with a yield of 4.5, 4.1, 4.0, 4.0, 4.0, 3.9, 3.6, 3.3, and 3 t ha^{-1}, respectively. Furthermore, IPB Var 6 grown in Unisan, Quezon had the lowest grain yield of 1.4 t ha^{-1}.

The relationship between agro-climatic variables and corn yield of IPB Var 6 is shown in Table 2. Rainfall showed a non-significant position correlation (r^2 = 0.175) with yield. The higher the rainfall, the greater the yield. Corn production increases when the correct amount of rain falls in the right place at the right time. As a result, having the right amount of rain in the right pattern is critical for corn yield (Cudjoe et al., 2021). According to the results

Table 2. Correlation coefficients between agro-climatic variables and the corn yield of IPB Var 6.

Climatic variable	Correlation coefficient
Rainfall	0.175
Maximum Temperature	-0.161
Minimum Temperature	-0.207
Mean temperature	-0.201
Relative humidity	-0.165

**Significant at 0.01 level of probability; *significant at 0.05 level of probability.

Table 3. Correlation matrix of agro-climatic variables.

	Rainfall	$Temp_{min}$	$Temp_{max}$	$Temp_{mean}$	Relative humidity
Rainfall	-	-0.976**	-0.738*	-0.936**	-0.755*
$Temp_{min}$		-	0.675*	0.915**	0.694*
$Temp_{max}$			-	0.915**	1.000**
$Temp_{mean}$				-	0.925**
Relative humidity					-

Significant at 0.01 level of probability; *significant at 0.05 level of probability; **$Temp_{min}$, minimum temperature; **$Temp_{max}$**, maximum temperature; **$Temp_{mean}$**, mean temperature.

obtained by Kar et al. (2007) and Asseng et al. (2001), low crop yields are caused by insufficient or no rainfall throughout crucial stages of plant development. Because of its demand for water for cell elongation and inability to limit vegetative development, corn is particularly vulnerable to climate change. The most important climatic variable impacting agricultural yield variations was average rainfall throughout the planting season (Neenu et al., 2013). Cudjoe et al. (2021) showed, however, that when rainfall is above normal, it causes waterlogging, which reduces corn yield. Magehema et al. (2014) also discovered that if rainfall exceeds normal levels, the incremental advantage to corn yield falls. It also backs up the findings of Rashid and Rasul (2011), who determined that corn requires a fixed amount of water and that increasing rainfall enhances production up to a point before grain yield starts to decrease.

The results of the study discovered that the temperature generally showed a negative correlation with yield. It was related to the study of Oke (2016), who observed that all temperatures showed a negative relationship with yield. This could be seen from negative coefficients for minimum temperature (r^2= -0.207), maximum temperature (r^2= -0.161), and mean temperature (r^2= -0.201). This means that the higher the temperature, the lower the corn yield, and the lower the temperature, the higher the yield. In a related study, Joshi et al. (2011) discovered that as temperature increased, corn yield decreased. Cudjoe et al. (2021) observed that when the temperature rises, corn yields fall. Corn yields increased somewhat despite the fact that the temperature continued to rise. This is due to the fact that it has also received a lot of rain. This indicates that the right amount of rain and distribution pattern can help corn yields be less affected by temperature. Omoyo et al. (2015) discovered an inverse relationship between corn grain yield and max temp. Furthermore, Hatfield and Prueger (2015) discovered that higher temperatures had the greatest effect during the reproductive development stage, with grain yield in corn reduced by up to 80–90% in all cases when compared to a normal temperature regime. Relative humidity had a negative correlation with the corn yield in general. According to Agritech (2021), relative humidity is negatively correlated with the grain yield of corn under high relative humidity. Similarly, high relative humidity reduces wheat grain yield. It can be attributed to the negative effect of relative humidity on pollination as well as to the high pest incidence. Omoyo et al. (2015) discovered that increasing temperatures and low relative humidity promote agricultural crop evapotranspiration as well as the related changes in inter-season rainfall, which have an effect on corn germination rate, grain filling, and growing season duration.

According to the findings of the climatic variables correlation matrix (Table 3), rainfall had a significant negative relationship with relative humidity and maximum temperature. However, it presented a highly significant and negative relationship with the minimum temperature and mean temperature.

An increase in rainfall significantly decreased maximum temperature (r^2= 0.738) and relative humidity (r^2= 0.755), and highly significantly decrease in minimum temperature (r^2= 0.976) and mean temperature (r^2= 0.936). According to Mawonike and Mandonga (2017), temperature effects rainfall in a variety of ways; for example, a high temperature might result in a high rate of potential evaporation and little precipitation. In some circumstances, high temperatures cause more evaporation and, as a result, more condensation, resulting in heavy rain (Nkuna and Odiyo, 2016). Furthermore, relative humidity influences the amount of rainfall received; when relative humidity is high (above 80%), rainfall is maximized. Moreover, Mawonike and Mandonga (2017) discovered that the interaction of temperature and relative humidity had a limited effect on the amount of rainfall received, accounting for just around 20% of the variation in rainfall. Despite the minimal degree of interaction between these variables, the positive coefficients imply that temperature and relative humidity have a positive correlation with rainfall. The increase in minimum temperature was followed by an increase in maximum temperature (r^2= 0.675), mean temperature (r^2= 0.915), and relative humidity (r^2= 0.694), as expected. Increases in maximum and mean temperature increased relative humidity, with highly significant positive coefficients (r^2=1.000) and (r^2= 0.925). This means that a rise in relative humidity was significantly related to a rise in temperature. Although the correlation between temperature and humidity varies by region, at all levels of humidity, variations in specific humidity correlate positively with temperature variations at the same level (Sun and Oort, 1995).

Conclusion

The yield indicated that the corn yield of IPB Var 6 is correlated to rainfall in the Philippines. Corn yield is negatively related to minimum and maximum temperatures, and also relative humidity. When the temperature increases, the yield declines, and when the temperature decreases, the yield increases. The availability of rainfall usually translates into a higher corn yield. Given the relationship between rainfall amount and corn yield, especially in the Philippines, which is rainfed or dependent on natural rainfall, the findings can be used to plan suitable adaptation strategies for farmers to use in corn production, suitable crops to suit the prevailing conditions and the adjustment of the cropping calendar due to changes in rainfall patterns.

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