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Original Article

Abiotic factors: Its relationship on the yield of mango (*Mangifera indica* L.) with science and technology interventions

Normina A. Mamalinta[1*] and Junito P. Marcelino[1]

ABSTRACT

The study investigated the impact of abiotic factors on the yield of harvested mangoes before and after Science and Technology (S&T) interventions in five municipalities, namely: President Quirino, Sultan Kudarat, Tulunan, North Cotabato, Tantangan, South Cotabato, Malungon, Sarangani Province, and General Santos City. The study used the simple linear regression model Y=βX + α to determine the extent to which there was a linear relationship between a dependent variable and one or more independent variables. In simple linear regression, a single independent variable, ie, rainfall or temperature, was used to predict the value of a dependent variable, the yield of mangoes per hectare during the first and second cycle productions of farmer-cooperators in four provinces, namely: Sultan Kudarat, North Cotabato, South Cotabato and General Santos/Sarangani. The results indicated that the General Santos/Sarangani Province obtained the highest yield in terms of baseline yield after two years of interventions. The derived regression model for rainfall (mm), temperature (°C), relative humidity (%), and soil pH was unable to predict the yield of mangoes in all provinces studied during the second production cycle of the farmer-cooperators. Conversely, the regression model for temperature (°C) and relative humidity (%) statistically predicted the yield of mangoes (t ha^{-1}) of farmer-cooperators in Sultan Kudarat during the first cycle of production. Additionally, rainfall (mm),

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[1]College of Agriculture, Sultan Kudarat State University, ACCESS Campus, EJC Montilla, Tacurong City, Sultan Kudarat, Philippines

***Corresponding Author.** Address: College of Agriculture, Sultan Kudarat State University, ACCESS Campus, EJC Montilla, Tacurong City, Sultan Kudarat, Philippines; Email: norminamamalinta@sksu.edu.ph

temperature (°C), and relative humidity had linear relationships with the yield of mangoes per hectare. However, soil pH showed fluctuating, curvilinear relationships with the yield of mangoes per hectare. Additionally, rainfall (mm), temperature (°C), relative humidity (%), and soil pH did not show significant relationships with the yield of mangoes per hectare.

Keywords: Temperature, relative humidity, soil pH, linear relationship, mangoes, yield

INTRODUCTION

Mango (*Mangifera indicaL.*) is an extensively cultivated fruit throughout the tropics and subtropics (Bally 2006, Prusky et al 2009), belonging to the family Anacardiaceae. Known as the king of fruits, mangoes have a wide ecological range, succulent taste, excellent flavor, high nutritive and medicinal value, as well as great religious and literal significance (Lakshmi et al 2011). The crop is grown in over 87 countries, with developing countries accounting for about 98% of total production while developed countries account for 80% of world import trade.

Mangoes are largely perishable and have a short shelf life of 2-4 weeks at 10-15°C, which limits their vacuity in fresh requests. Shelf stability and quality can be threatened by insect quarantine treatments, chilling temperatures, and fungal rot, which can induce abiotic or biotic stress on the fruit. As a result, mango production heavily relies on chemical applications for pest management, requiring intensive (Salyani 2004) spraying from flushing, flowering, and fruit set, until the maturity of the fruit. The main thing of scattering is to deliver an effective, invariant cure of spray accouterments to the intended targets in a safe and timely manner (Deveau 2009). Kathirvel et al (2002) emphasized that chemical crop protection and high-yield demand are the most critical operations in orchard crops. They also noted that pests are a significant challenge in agriculture, causing an average annual loss of around 33% of potential agricultural production worldwide.

Diseases are a major constraint in mango production, particularly during the rainy season when moisture is abundant for the favorable growth of disease-causing pathogens. Anthracnose caused by *Colletotrichum gloeosporiodes* is the major pre and postharvest disease of mango in all mango-producing areas in the world (Fitzell and Peak 1984, Dodd et al 1991), infecting almost all parts of the plant. It infects nearly all parts of the mango tree, including flowers, panicles, outgrowths, leaves, and both mature and immature fruits. The disease can cause significant yield loss, particularly in flowers, where large numbers of infected flowers wither and tiny fruits develop black sunken spots during ripening (Eusebio 1998).

The S&T Anchor Program for Mango, which includes a recent UPLB-PCAARRD-DOST project, has developed a spray program that can effectively reduce the incidence and severity of anthracnose and stem-end rot below 10% at harvest. When used in combination with improved cultural management practices such as pruning, fertilization, sanitation, and bagging, the spray program has demonstrated a significant reduction in the incidence of these diseases (S&T Anchor Program for Mango Project 1.2, Phase 1, Terminal Report 2004). Both SMARRDEC and CLARRDEC have successfully implemented this pre-harvest disease management program as part of their S&T-based mango farming initiatives. Consequently, this study explores the impact of abiotic factors on mango yield, considering the influence of science and technology interventions.

MATERIALS AND METHODS

Research Design

In this study, a developmental-simple linear regression research design was adopted to examine the relationship between abiotic factors and mango yield in the context of science and technology interventions. The analysis was conducted to establish a regression analysis between abiotic factors and mango yield, considering the impact of S&T-based interventions.

Identification of Grower-Cooperators

The identification of grower-cooperators for this study was based on the recently conducted project on S&T-based interventions for mango production, which focused on ICM, IPM, and GAP adoption in Region 12. The twenty (20) cooperators were the farmers who received S&T-based interventions in mango production. The study analyzed the regression between abiotic factors and mango yield over two consecutive production cycles using data from these cooperators.

Benchmark Survey and Interview

A benchmark survey and interviews were conducted on the identified grower-cooperators to evaluate their cultural practices in mango production activities. A structured survey questionnaire was used to gather relevant data. Individual records of each grower-cooperator were documented to serve as a basis for intervention and revalidation of practices that require improvement in their production activities.

S & T Interventions in Mango Production

The mango ICM/IPM practices and GAP guidelines were implemented on the farms of each grower-cooperators. Comprehensive monitoring of all production activities and practices was conducted, and relevant data were collected and recorded for analysis.

ICM/IPM practiced and GAP guidelines for mango:

Pruning

Pruning involves the removal of unnecessary branches such as water sprouts, dried, disease-infected branches, and all branches that grow towards the center of the canopy. Pruning was done after harvest to minimize pest infestation; open-center pruning was also done.

Nutrient Management

Soil and tissue analysis were done before the application of fertilizers. Samples were sent to the Bureau of Soils and Water Management (BSWM), and the results were documented for future reference. The following fertilization schedule was done.

Age of the trees (in years)	Fertilization schedule/program (per tree)
5-6	500g -1kg of 14-14-14 + 3-4kg of organic fertilizer
7-8	2kg of 14-14-14 + 4-5kg of organic fertilizer
9-10	3kg of 14-14-14 + 5-6kg of organic fertilizer
11-15	5kg of 14-14-14 + 10kg of organic fertilizer
16-20	6-7kg of 14-14-14 + 12kg of organic fertilizer
More than 20	10kg of 14-14-14 + 15-20kg of organic fertilizer

The above-mentioned quantity of fertilizer was split evenly and applied at the beginning and the end of the rainy season. It was placed in a shallow canal or 6-8 holes dug around the tree at a depth of 15cm-30cm and a distance of 2m and 4m radius from the trunk. At 18-25 days after flower induction and before bagging, foliar fertilizer was applied as a supplement to the soil-applied fertilizer. The foliar fertilizer was applied with macro and micronutrients such as zinc, boron, magnesium, and calcium. A complete set of records of fertilizer applications was kept.

Paclobutrazol Application

The most commonly used growth regulator in mango is paclobutrazol. It inhibits gibberellin, a naturally occurring hormone that promotes vegetative growth. The restriction of this hormone allows a shorter duration of vegetative growth and permits the build-up of carbohydrate reserves. This will result in earlier and consistent flowering leading to higher yield. The proper use of paclobutrazol may lead to consistent flowering, optimum yield, timely schedule of harvesting and successful off-season production. Paclobutrazol was applied for one to three months after flushing at the rate of 1g ai (4mL formulated product) per linear canopy diameter and diluted in 1L of water. Paclobutrazol solution was drenched within the active root zone and kept the soil moist for several weeks to maximize uptake of paclobutrazol.

Flower Induction

Before spraying, the leaves of trees were checked for attributes of readiness to flower as follows: the age of the leaves should be at least 7 months from flushing;

leaves are dark green, coppery, and brittle; and buds are prominent and dormant. Nitrate-based products (ie, potassium nitrate, calcium nitrate, sodium nitrate, calcium ammonium nitrate, liquid ammonium nitrate) for use as flower inducers, whether of agricultural grade or formulated products were done. The flower inducer was sprayed by wetting the leaves thoroughly with spray concentration. During the rainy months, higher concentrations (3%) of flower inducers were applied, while during the dry months, lower concentrations (1.5%) were utilized.

Flower and Fruit Management

Foliar application of liquid fertilizer at 18-22 days after flower induction (DAFI) was performed to promote flower growth and development. Pollination by insects, such as like blue flies and bees, was facilititated by avoiding the use of insecticides during full bloom (26-28 DAFI). During periods of rainy full bloom, flowers were sprayed with fungicide immediately after the rain to prevent fungal growth. Fungal growth was also mitigated by gently shaking the branches to remove rainwater from the flowers and to remove any disease-infected flowers.

Fruit Bagging

Fruit bagging is practiced to improve the quality of mango fruits. It increases fruit acceptability by reducing damages from pests and diseases and other causes of rejection such as latex burn, wind scar, etc. Spraying of pesticides after bagging may be necessary if ants, scale insects, and mealy bugs are present inside bags.

Fruit bagging was performed individually at 55 to 60 days after flower induction (DAFI). Early bagging (45-50 DAFI) was done for cecid fly infestation. During rainy months, late bagging (60-70 DAFI) was done also to extend chemical fruit protection and to minimize mealy bug colonization of the fruits.

Field Sanitation

Sanitation is analogous to cleanliness. It involves the removal of infected fruits, leaf litter, and other plant debris. Weeds and other unwanted plants around mango trees were removed to reduce the initial pest population and sources of inoculum throughout the production period. This is particularly effective against cecidflies, fruit flies, and anthracnose.

Harvesting

Fruits were harvested upon reaching maturity of 105-130 DAFI. On-season harvesting was done 105 to 115 DAFI, and off-season harvesting was done 120 to 130 DAFI. Fruits were harvested between 9:00AM and 3:00PM for lower latex inflow. It was done by leaving about 2.0cm pedicels on the fruit to minimize latex flow which may burn the fruit. Harvested fruits were kept away from direct sunlight and brought immediately to the shade for sorting and other post-harvest activities.

Statistical Analysis

This study utilized the simple linear regression model, expressed as $Y=\beta X+\alpha$, to examine the linear relationship between a dependent variable and independent variable and independent variables. The simple linear regression approach involves the use of a single independent variable to predict the value of a dependent variable. Specifically, in this study, simple linear regression was used to analyze the impact of independent variables, including rainfall (mm), temperature (°C), relative humidity (%), and soil pH, on the dependent variable of mango yield in tons per hectare. This was conducted across four provinces, namely Sultan Kudarat, North Cotabato, South Cotabato, and General Santos/Sarangani, over two consecutive production cycles of the participating farmer-cooperators.

RESULTS AND DISCUSSION

Yield of Harvested Mangoes (t ha^{-1})

The province of General Santos/Sarangani recorded the highest baseline yield of 9.21t ha^{-1}, followed by South Cotabato and North Cotabato provinces with yields of 8.58t ha^{-1} and 8.10t ha^{-1}, respectively. The lowest baseline yield of 7.41t ha^{-1} was observed in Sultan Kudarat province (Table 1).

After two years of interventions, General Santos/Sarangani province had the highest average yield of 11.84t ha^{-1}. North Cotabato and Sultan Kudarat provinces had an average yield of 11.37t ha^{-1} and 10.85t ha^{-1}, respectively. South Cotabato province had an average yield of 10.55t ha^{-1} (Table 2).

Table 1. Baseline yield (t ha^{-1}) of harvested mangoes before S&T interventions in provinces.

Province	Yield (t ha^{-1})
General Santos City/Sarangani	9.21
South Cotabato	8.58
North Cotabato	8.10
Sultan Kudarat	7.41

Table 2. Yield (t ha^{-1}) of harvested mangoes after two years with S&T interventions in provinces.

Province	Yield (t ha^{-1})
General Santos City/Sarangani	11.84
South Cotabato	10.55
North Cotabato	11.37
Sultan Kudarat	10.85

Rainfall

Results indicate that there were linear relationships (Figure 1) between rainfall and yield of mangoes in most areas except for General Santos/Sarangani area during the first cycle production, which had a fluctuating relationship with a curvilinear trend line (Figure 1 d1). The coefficient of determination (R-squared or R^2) ranged from 58.74% (R^2=0.5874) to 5.49% (R^2=0.0549), indicating that the variability of rainfall had a moderate to very low influence on the yield of mangoes (Table 3). Further, the regression model developed as a result of the regression analyses of data can statistically but not significantly predict the relationships between rainfall and yield of mangoes per hectare.

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Table 3. Summary table for the rainfall analysis of regression in the provinces during the first cycle production.

Province	Beta (*β*) Coefficient	Alpha (*α*) Coefficient	Multiple R	R Square	*t*-Stat	*p*-value
Sultan Kudarat	-0.0883	20.6768	0.7664	0.5874	-2.0665	0.1307
North Cotabato	-0.0582	15.6866	0.6906	0.4769	-1.6538	0.1967
General Santos/Sarangani	-0.0210	13.4010	0.6068	0.3682	-1.3221	0.2779
South Cotabato	-0.0107	9.8829	0.2343	0.0549	-0.4174	0.7045

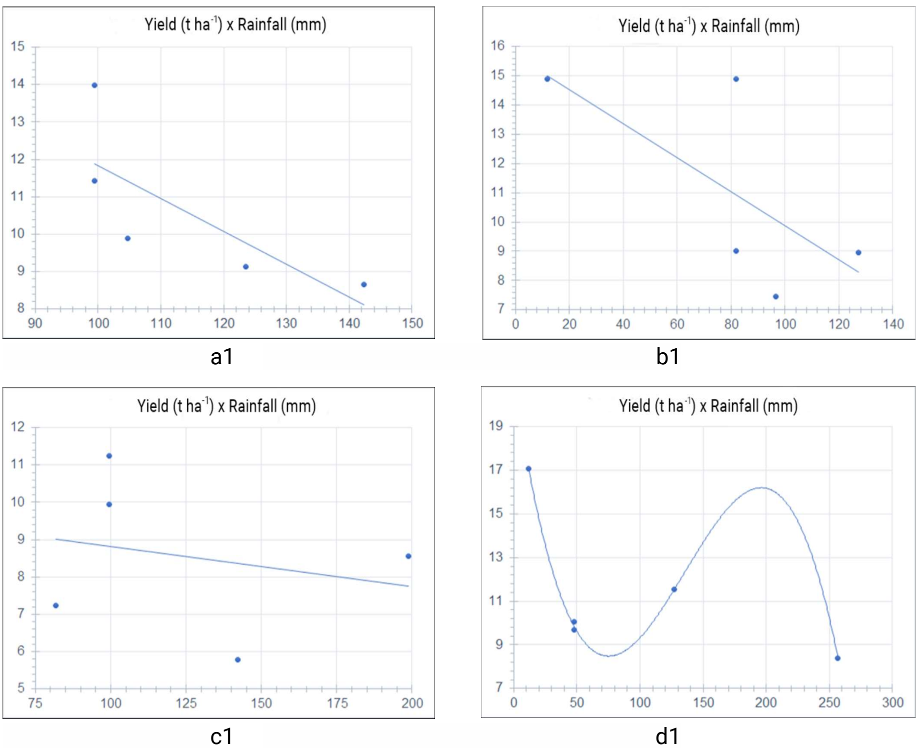


Figure 1. Scatterplot diagram of the relationships of independent variable expressed as Y=βX+α - rainfall (mm), and the dependent variable yield of harvested mangoes (t ha^{-1}) during the first cycle production of grower-cooperators in (a1) Sultan Kudarat, (b1) North Cotabato, (c1) South Cotabato and (d1) Gen. Santos/ Sarangani Province.

Temperature

Effects of temperature (°C) on the yield of mangoes per hectare showed that in the Sultan Kudarat area, it significantly influenced the yield of mangoes per hectare during the first cycle production of the farmer-cooperators.

The regression equation Y=3.3443(X) + (-81.6157) reveals that the yield of mangoes increased by 3.3443 tons per hectare for every 1°C increase in temperature (Table 4). The regression model, derived from data analysis, statistically and significantly predicts the yield of mangoes, indicating that any variability in the yield of mangoes is attributable to temperature, with a coefficient of determination of 0.8245 or 82.45% (Table 4). All other areas and production cycles did not have a regression model that was statistically significant for predicting the yield of mangoes based on temperature. In those cases, the coefficient of determination (R^2) ranges from 0.4866 (Table 4) to 0.1771 (Table 5), indicating a moderate to very low influence of temperature on the yield of mangoes. Overall, however, the yield of mangoes per hectare exhibits a linear relationship with the average daily temperature, as shown in the different scatterplot diagrams (Figure 2).

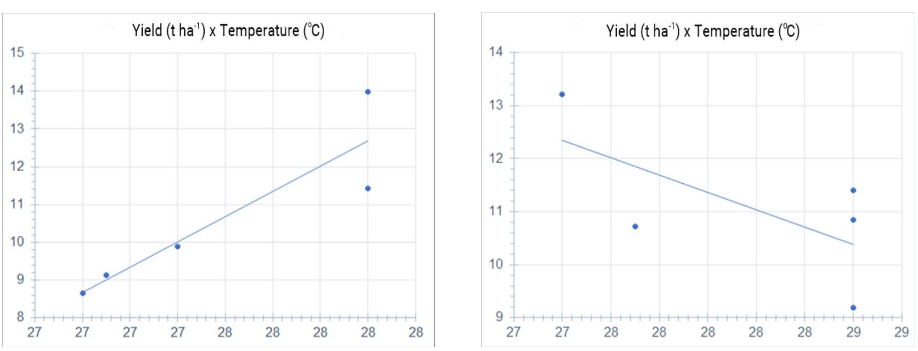
This result is supported by the information provided at http://www.nda.agri.za /docs/Infopaks/mango.htm, which indicates that mango trees thrive and produce well in high-temperature areas. Conversely, low temperatures during full bloom can cause the fruit to develop to approximately the size of a golf ball, turn yellow, and ultimately abort. A significant number of these aborted fruits can lead to a reduction in overall yield.

Table 4. Summary table for the temperature analysis of regression in the provinces during the first cycle production.

Province	Beta (*β*) Coefficient	Alpha (*α*) Coefficient	Multiple R	*R* Square	*t*-Stat	*p*-value
Sultan Kudarat	3.3443	-81.6157	0.9080	0.8245	3.7544	0.0330
North Cotabato	3.2421	-78.9577	0.6578	0.4327	1.5126	0.2276
General Santos/Sarangani	1.1431	-20.7551	0.4353	0.1895	0.8374	0.4638
South Cotabato	2.1962	-51.9281	0.6976	0.4866	1.6862	0.1903

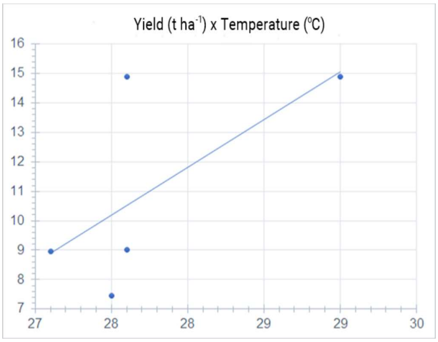
Table 5. Summary table for the temperature analysis of research on the provinces during the 2nd cycle production.

Province	Beta (*β*) Coefficient	Alpha (*α*) Coefficient	Multiple R	*R* Square	*t*-Stat	*p*-value
Sultan Kudarat	-1.6377	57.2269	0.6609	0.4368	-1.5253	0.2246
North Cotabato	2.5000	-59.3600	0.4777	0.2282	0.9418	0.4158
General Santos/Sarangani	2.0021	-43.7283	0.6631	0.4397	1.5344	0.2225
South Cotabato	-1.5870	56.7826	0.4208	0.1771	-0.8035	0.4805



a1 a2

Figure 2. Scatterplot diagram of the relationships of independent variable expressed as Y=βX+α-temperature (°C), and the dependent variable yield of harvested mangoes (t ha^{-1}) during the first and second cycle production of grower-cooperators in (a1, a2) Sultan Kudarat, (b1, b2) North Cotabato, (c1, c2) South Cotabato and (d1, d2) Gen. Santos/ Sarangani Province.



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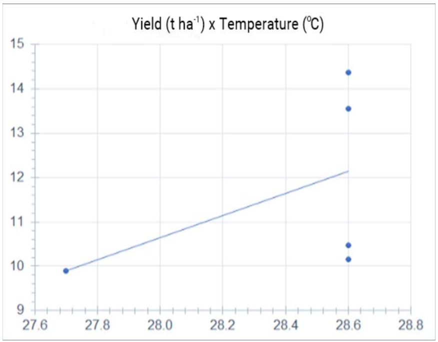

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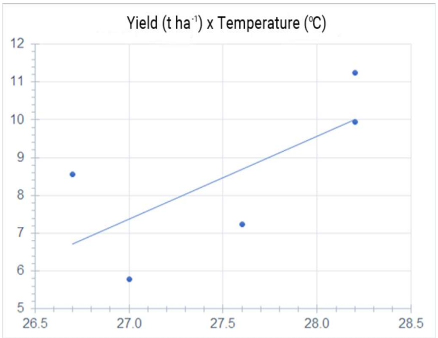

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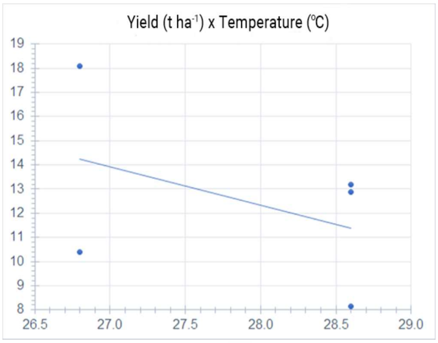

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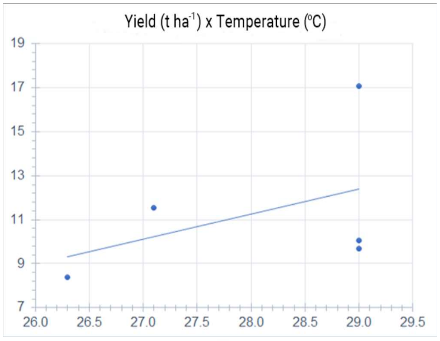

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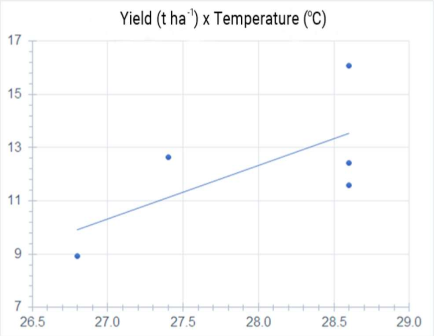


c2

Figure 2 continued

Relative Humidity

A very similar result was observed regarding the relationship between the yield (t ha^{-1}) of mangoes and relative humidity (RH, %). However, a negative relationship exists between relative humidity and the yield of mangoes per hectare. The regression model Y=-0.8245(X) + 76.9121 shows a negative response of mangoes on RH. The equation indicates that the yield of mangoes (t ha^{-1}) decreases by 0.8245t ha^{-1} for every 1% increase in RH. The coefficient of determination (R^2) of 0.7767 shows that 77.67% of the variability in the yield of mangoes was attributed to RH; thus, an increase in RH results in a decrease in the yield of mangoes per hectare

(Table 6). The results further indicate that the model statistically and significantly predicts the dependent variable (yield/ha of harvested mangoes) during the first production cycle of grower-cooperators in Sultan Kudarat. All other areas did not show any significant impact of relative humidity on the yield of mangoes per hectare. Most of these areas exhibited a negative effect of relative humidity on the yield of mangoes Figure 3). In the General Santos area, a fluctuating effect of relative humidity was observed (Figure 3)(d1).

In this context, Pusky (as cited by Research Gate 2017) claimed that a map of average daily maximum RH during fruit growth [of mangoes] can be used as a basis for predicting the incidence of black spots, which affect fruit development and, consequently, yield per hectare.

Table 6. Summary table for the relative humidity analysis of regression in the provinces during the 1st cycle production.

Province	Beta (β) Coefficient	Alpha (α) Coefficient	Multiple R	*R* Square	*t*-Stat	*p*-value
Sultan Kudarat	-0.8245	76.9121	0.8813	0.7767	-3.2302	0.0482
North Cotabato	-0.7082	66.2802	0.6589	0.4342	-1.5173	0.2265
General Santos/Sarangani	-0.4681	48.4167	0.6356	0.4040	-1.4260	0.2491
South Cotabato	-0.3343	35.1655	0.4194	0.1759	-0.8002	0.4821

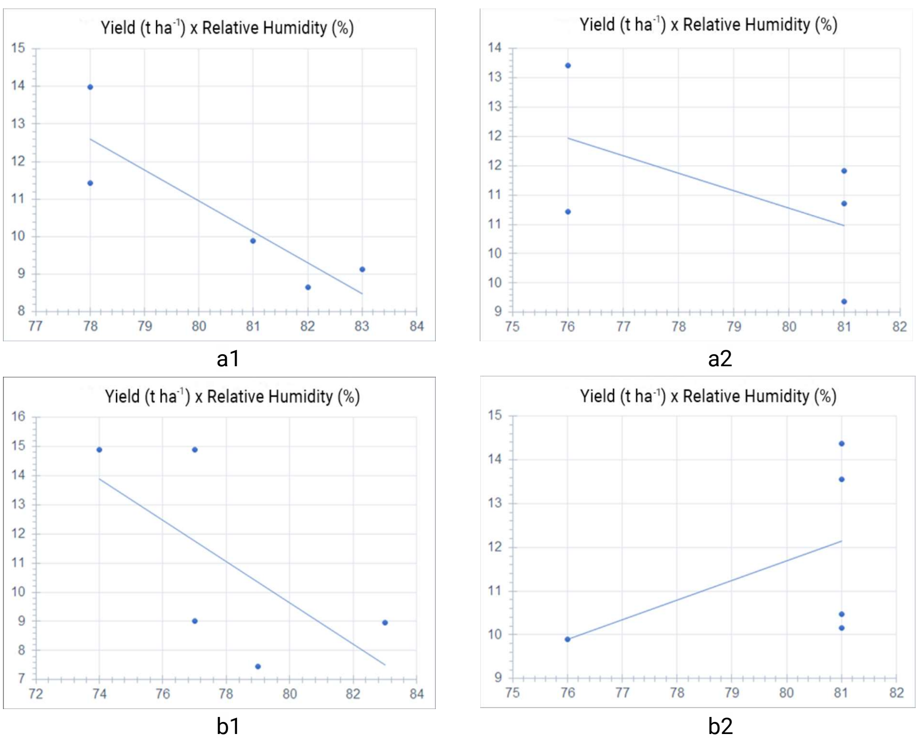
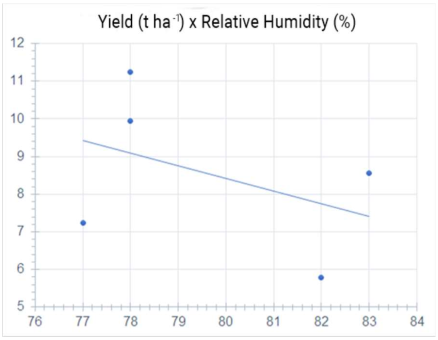


Figure 3. Scatterplot diagram of the relationships of independent variable expressed as Y=βX+α-relative humidity (RH, %), and yield of harvested mangoes (t ha^{-1}) during the first and second cycle production of grower-cooperators in (a1, a2) Sultan Santos/Kudarat, (b1, b2) North Cotabato, (c1, c2) South Cotabato and (d1, d2) Gen. Sarangani Province.



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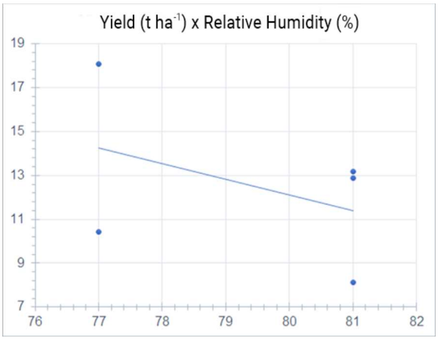

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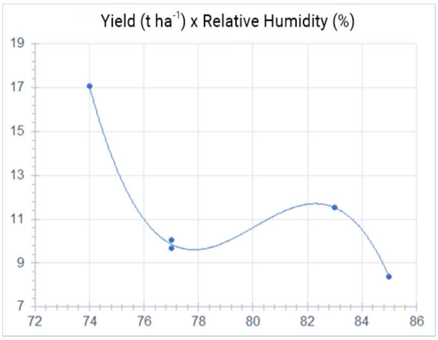
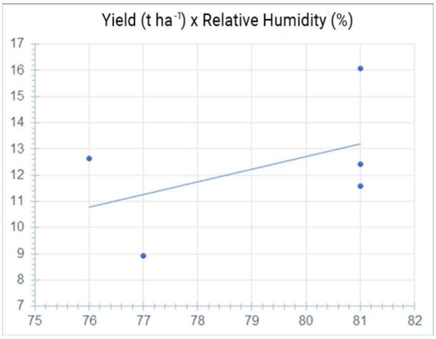


d1

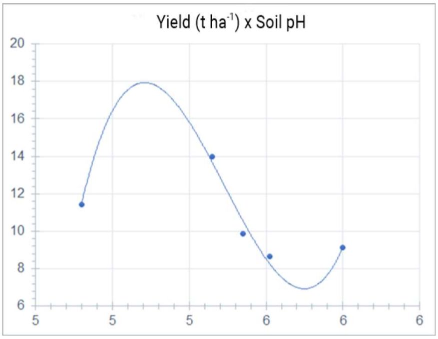


d2

Figure 3 continued

Soil pH

In all areas of the study and production cycles, it was found that soil pH did not have a significant impact on the yield of mangoes per hectare in all areas and production cycles. The regression model did not correctly predict the yield of mangoes due to the fluctuating relationships between these two variables (Figure 4).



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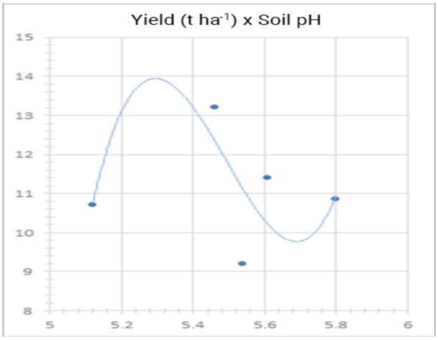

a2

Figure 4. Scatterplot diagram of the relationships of independent variable expressed as Y=βX+α-soil pH, and yield of harvested mangoes (t ha^{-1}) during the first and second cycle production of grower-cooperators in (a1, a2) Sultan Kudarat, (b1, b2) North Cotabato, (c1, c2) South Cotabato and (d1, d2) Gen. Santos/ Sarangani Province.

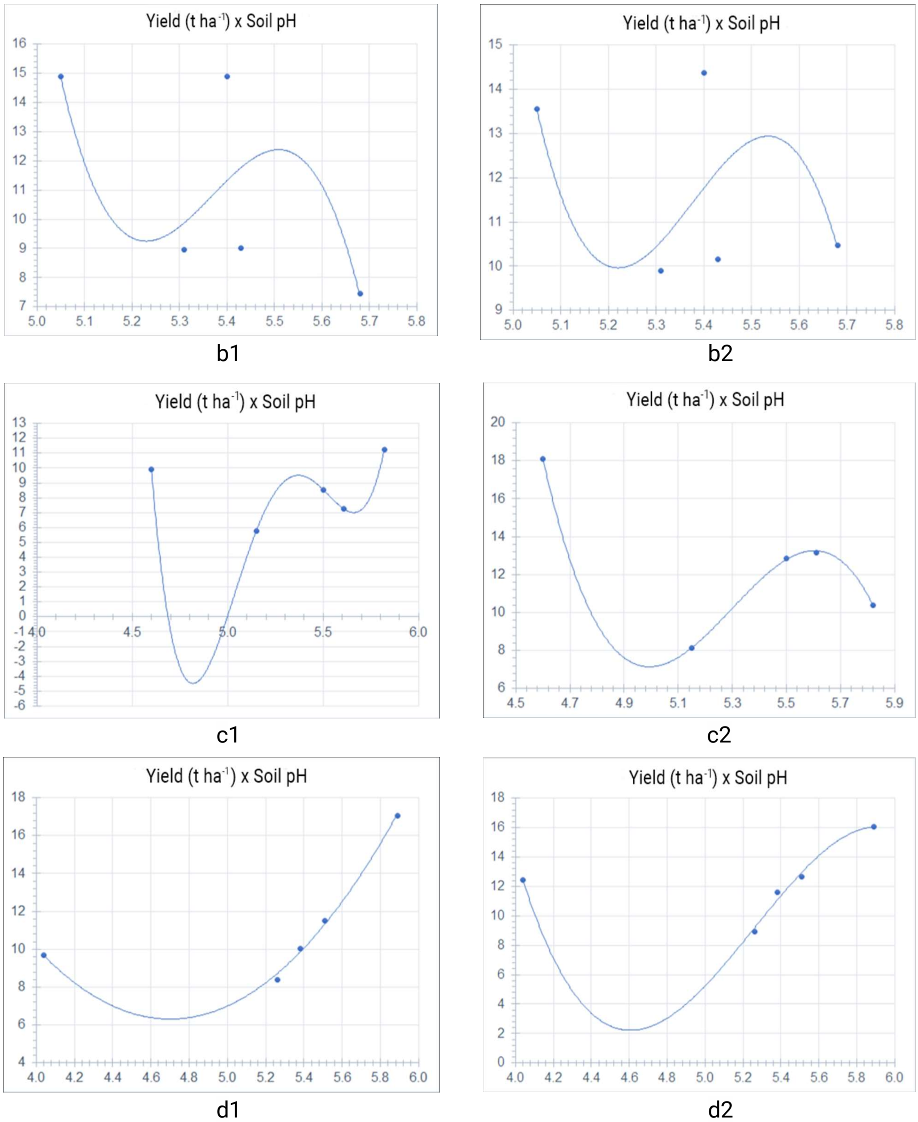

Figure 4 continued

CONCLUSION AND RECOMMENDATION

The results show that the General Santos/Sarangani province obtained the highest yield in terms of baseline yield after two years of interventions. The derived regression model for rainfall (mm), temperature (°C), relative humidity (%), and soil pH could not predict the yield of mangoes in all provinces studied during the second production cycle of the farmer-cooperators. Conversely, the regression model for temperature (°C) and relative humidity (%) statistically predicts the yield of mangoes (t ha^{-1}) for farmer-cooperators in Sultan Kudarat during the first cycle of production. Additionally, rainfall (mm), temperature (°C), and relative humidity exhibit linear relationships with the yield of mangoes per hectare. However, soil pH displayed fluctuating, curvilinear relationships with the yield of mangoes per hectare. Moreover, rainfall (mm), temperature (°C), relative humidity (%), and soil pH did not demonstrate significant relationships with the yield of mangoes per hectare.

RECOMMENDATIONS

To increase the yield per hectare, flowering and fruit settings should be timed when temperature is about 27 to 28°C and relative humidity is about 78% to 79%. Also, to develop a regression model that would accurately predict the yield of mangoes per hectare due to rainfall, temperature, relative humidity, and soil pH, more data samples should be used. In addition, a similar study should be conducted in other areas with a greater number of farmer-cooperators using a multiple regression model to determine the combined effects of the different independent variables (rainfall, temperature, relative humidity, and soil pH) on the yield of mangoes per hectare.

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AUTHOR CONTRIBUTIONS

NAM designed the study, collected data, analyzed data, and wrote the paper. JPM concetualized the study, reviewed data analysis and writing, and wrote the paper.

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The authors fund this research.

AVAILABILITY OF DATA AND MATERIALS

Data available within the article.

ETHICAL CONSIDERATION

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare that there are no conflict of interest.

REFERENCES

Bally SE. 2006. Mangifera indica (mango): Anacardiaceae (cashew family). Species Profiles for Pacific Island Agroforestry, Ver. 3.1, April 2006 (pp1-25)

Deveau J. 2009. Six Elements of Effective Spraying in Orchards and Vineyards. Factsheets No. 09-039, AGDEX 065. Retrieved from http://www.ontario.ca/omafra

Eusebio AA. 1998. Disease Management System For Mango Anthracnose. Unpublished MS Thesis. University of the Philippines, Los Banos, College, Laguna

Fitzell RD. 1984. The Epidemiology of Anthracnose Disease of Mango: inoculums sources, spore production and dispersal. Ann. *Applied Biology* 104:53-59

Gundappa P. 2014. Migratory behavior of mango hoppers, idioscopus spp.in relation to host plant flowering phenology: a synchronous shift. *The Bioscan* 9(2):639-641.http://www.nda.agri.za/docs/Infopaks/mango.htm

Kathirve K and Manian R. 2002. Development and Evaluation of Power Tiller Operated Orchard Sprayer. Agricultural Mechanization in Asia, Africa and Latin America. 33(3)

Lakshmi BKM. 2011. Cross-infection potential of Colletotrichum gloeosporioides penz. Isolates causing anthracnose in subtropical fruit crops. *Tropical Agricultural Research* 22:183-193

Pusky 2017. Effect of Relative Humidity during Mango Growth on the Incidence of Quiescent Infection of Alternaria alternata

Ploetz R and Ploetz R. 2003. Diseases of Tropical Fruit Crops. *CABI Publishing* 327-363

Salyani M. 2004. Spray Penetration and Deposition Tree Canopies. *Transactions of ASAE* 47(3):619-627

S &T Anchor Program for Mango Project 1.2 (Phase 1) Terminal Report. 2004. United States Department of Agriculture-Agicultural Marketing Service. Mango promotion, research, and information order (proposed). http://www.ams.usda .gov/fv/rpmango.htm Accessed August 2003