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Development of Regression Model for Summer Okra under Different Plastic Mulches and Irrigation Regimes

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Abstract

A field experiment was conducted during the summer seasons of 2017 and 2018 at VNMKV, Parbhani to evaluate the effects of different plastic mulches and irrigation regimes on soil moisture conservation and yield prediction of summer okra (*Abelmoschus esculentus* L. Moench). The study employed a split plot design with three irrigation levels (80%, 100%, and 120% ETc) and four mulch treatments (transparent, black, silver-black plastic mulch, and no mulch). Key agronomic, environmental, and biological parameters such as soil moisture, soil temperature, microbial population, and plant growth traits were recorded. Significant positive correlations were found between okra yield and root length, plant height, microbial population, and soil moisture. Among the mulches, silver-black plastic mulch demonstrated superior performance in maintaining optimal soil moisture and temperature, resulting in the highest fruit yield. Multiple regression analysis using SPSS revealed that root length and plant height was the most influential variables for yield prediction. The developed pooled regression model, Y = -134.094 + 4.317*Root length + 1.614*Plant height, R^2= 0.93 indicating strong predictive ability. The findings underscore the effectiveness of integrating plastic mulching and optimized irrigation in enhancing okra productivity under semi-arid conditions and provide a scientific basis for informed agronomic decision-making.

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Keywords

Okra, Drip irrigation, Plastic Mulch, model.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is one of the most important vegetable crops grown in tropical and subtropical regions, including India. It is rich in vitamins, minerals, and dietary fiber and holds substantial economic importance for small and marginal farmers. Okra cultivation during the summer season, however, faces several agronomic constraints such as high temperature, moisture stress, and rapid soil water loss due to increased evapotranspiration (Ali *et al.,* 2011). Efficient management of soil moisture is crucial to ensure healthy plant growth and optimum yields under such conditions. Water scarcity and the need for more sustainable use of available water resources have made deficit irrigation and moisture conservation practices a key focus in crop production research. Plastic mulching is one such practice that has been widely adopted to conserve soil moisture, suppress weed growth, and improve soil temperature, thereby enhancing crop growth and productivity (Kumar *et al.,* 2018). Black polyethylene mulch and silver-colored mulch are particularly known for their ability to reduce soil evaporation and improve water use efficiency (Igbadun *et al.,* 2012). Concurrently, adjusting irrigation levels to match crop water requirements without over-application has been shown to significantly increase yield per unit of water used (Singh *et al.,* 2015).

The combined effects of mulching and regulated irrigation on okra have been studied in various agro-climatic zones; however, there remains a need for predictive modeling to assess the interactions of these variables. Regression modeling, particularly multiple linear regression, is a useful statistical tool that helps in predicting crop performance based on measurable input factors such as irrigation level, mulch type, and soil moisture content (Ghosh *et al.,* 2010). Such models enable better decision-making by quantifying the influence of each treatment factor and identifying optimal combinations for maximum yield. Therefore, the present study aims to develop multiple regression model for summer okra fruit yield and correlation analysis between okra yield and soil temperature, soil moisture, microbial population and plant growth parameters. This model will provide a scientific basis for recommending water- and mulch-use strategies in semi-arid regions where water resources are limited and conservation practices are essential for sustainable vegetable production.

Materials and Methods

Experimental Layout and Design

The field experiment was conducted in summer season during two consecutive years *viz.,* 2017 and 2018 on research farm of All India Co-ordinated Research Project on Irrigation Water Management, Vasantrao Naik Marathwada Krishi Vidyapeeth (VNMKV), Parbhani. Parbhani is situated at 409 m altitude, 19^{o}16'N latitude and 76^{o}47'E longitudes in Marathwada division of Maharashtra State. Parbhani is grouped under assured monsoon rainfall zone with an average annual precipitation of 918 mm.

The climate of the Parbhani lies in semi-arid and assured rainfall zone with an average annual precipitation of 897 mm and 42 rainy days. Most of the rain received during the period from June to September.

May is the hottest and December is the coolest month of the year. The atmospheric humidity is high from June to October (Dendage *et al.,* 2018). Daily meteorological data of Parbhani station used in the present investigation were collected from Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The weather condition during growing season of okra in 2017 and 2018 are presented in Table 1.

The soil was clayey in texture, low in total nitrogen and medium in available phosphorus, high in potassium and slightly alkaline in reaction. The field experiment was laid out in split plot design, in which three irrigation levels were assigned to main plots and four mulch treatment to sub plots. Thus, the experiment consisted of total 12 treatment combinations which were replicated thrice. All sub plot treatments were randomized in each main plot treatment.

Wherein main plots were assigned to three irrigation levels based on daily crop evapotranspiration (ET_C) data (I_1 – drip irrigation at 80 % of crop evapotranspiration (ET_C), I_2 – drip irrigation at 100% of crop evapotranspiration (ET_C) and I_3 – drip irrigation at 120% of crop evapotranspiration (ET_C)) and subplot to three plastic mulches transparent plastic mulch (TPM), black plastic mulch (BPM) and silver-black plastic mulch (SBPM) with control (without mulch). The spacing was 0.6 m row to row and 0.6 m plant to plant. Single seed of parbhani krinti varity of okra was dibbled at each hill on 28th Feb., 2017 and 28th Feb., 2018. Fertilizers were applied as per recommended doses for summer okra on AICRP on Irrigation Water Management, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, as 75:37.5:37.5 NPK kg/ha.

Estimation of irrigation water requirement

The daily irrigation water requirement for the okra crop was estimated by using the following relationship (Tiwari *et al.,* 1998(a))

$$\mathbf{IR = ET_c - R_e} \qquad (1)$$

Where,

IR = Net depth of irrigation (mm day^{-1})

ET_c = Evapotranspiration (mm day^{-1})

R_e = Effective rainfall (mm day^{-1})

The net volume of water required by a plant was calculated by the relationship

$$V = IR \times A \qquad (2)$$

Where,

V =Net volume of water required by a plant

A =Area under each plant (m^2) (spacing between rows, m x spacing between plants, m)

The effective rainfall is that part of the rainfall which is used for the consumptive use. At Parbhani, the average monthly rainfall from February to May is very low as compared to rest of the months and also the potential evapotranspiration during these months is higher as compared to other months.

Therefore rainfall occurring during these months was taken as effective rainfall (Michael, 2005). The irrigation water was determined after subtracting the effective rainfall from the total irrigation requirement (Eq.1).

Determination of soil moisture content

Soil samples were taken with screw auger and soil moisture was determined by Gravimetric method at 15 DAS, 30 DAS, 45 DAS, 60 DAS, 75 DAS and 90 DAS. The soil samples were taken at 10 cm from a lateral and at the soil depths of 0-7.5, 7.5-15, 15-30 and 30-45 cm as shown in Plate 3.1. The soil samples were dried at temperature of 105^0C ± 5^0C for a period of about 24 hours. The amount of water held by soil was calculated by using following equation,

$$\text{Moisture content (\%)} = \frac{(W_1 - W_2)}{W_2} \times 100$$

Soil temperature

Soil temperature (^{0}C) was measured between two plants at centre of each treatment plot by using digital soil thermometer (LCD multi-stem thermometer with accuracy ± 1^0C between – 50 to 200 ^{0}C) at 5, 10, 15, 20 cm depths by inserting sensor rod of digital thermometer in soil surface as shown in Plate 3.2.

The surface soil temperature and temperature of mulch material was recorded by using hand held digital infrared thermometer. The daily temperature of soil and mulch material was recorded in each plot at 7.24 a.m. and 2.24 p.m. (Local Standard Time) and averaged over the week at four depths every day between sowing and harvesting.

Soil microbial population

Soil moisture availability is an important factor, which influences the activity of micro-organisms in soil. The effect of plastic mulching on bacteria, fungi and actinomycetes population was studied at the time of harvest. Soil cores were sampled by penetrating the plastic mulch.

The mulching materials on the sampling points were carefully removed during the collection of soil samples. For all plots, soil at five randomly selected locations were sampled in two layers viz. 0-10 cm and 10-20 cm, referred to as the surface and sub-surface, respectively using an auger with a 5 cm internal diameter and then mixed as one sample. Total microbial populations of soil samples were determined in the Department of Soil Science and Agricultural Chemistry Laboratory, VNMKV, Parbhani.

Plant growth parameters

The periodic observations were recorded from the randomly tagged five plants in each treatment plot on growth and yield attributing characters of drip irrigated okra crop at 30, 60 and 90 days after sowing (DAS) (Parmer *et al.,* 2013). Following growth and yield attributing parameters were recorded.

Root length

Five plants were tagged at random in each treatment plot for recording the root length at harvest of summer okra crop. The root length was measured in cm, and average root length was determined.

Correlation and Regression Analysis

The correlation and multiple stepwise regression analysis between okra yield and various parameters observed during the study was worked out by using SPSS software. SPSS (currently officially "IBM® SPSS® Statistics") is a commercially distributed software suite for data management and statistical analysis and the name of the company originally developing and distributing the program (Frey, 2017).

The independent parameters like soil moisture, soil temperature, plant growth parameters and microbial population of soil were used for finding the relationship with okra fruit yield.

Results and Discussion

Co-relation of mean soil moisture and okra yield

Correlation studies between okra yield and mean soil moisture for different plastic mulches is presented in Figure 1.

Okra fruit yield increased as mean soil moisture increased. The plastic mulch affected soil moisture in the sequence of silver-black, black, transparent and the control. The highest okra yield (179.22 q/ha) was observed with maximum soil moisture (28.61 %) in silver-black plastic mulch and lowest okra yield was obtained in lowest soil moisture (24.97 %) in control (without mulch). There was significant positive correlation, $y = 23.431x - 484.73$; $R^2 = 0.942$ between fruit yield of okra and average soil moisture content.

Co-relation between mean soil temperature and okra yield

Relationship between okra yield and mean soil temperature for different mulches is presented in Figure 2.Mean soil temperature influenced okra yield (Figure 2). Silver-black plastic mulch recorded an average soil temperature of 30.17 ^{0}C and was associated with the highest okra yield. However, when soil temperature increased to about 31.28 ^{0}C in black plastic mulch and 33.05 ^{0}C in transparent plastic mulch, okra fruit yield decreased.

Results of co-relation study indicated that under the conditions specified, higher soil temperatures induced by the plastic mulches were negatively associated with total yield and positive trend with silver-black plastic mulch, recording higher total fruit yield of okra than control without mulch

Relationship between plant growth parameter and okra fruit yield

The co-relation between plant growth parameters and okra yield are presented in Table 2. Linear relationship was observed with okra fruit yield and plant growth parameters, with 0.97, 0.99, 0.98, 0.98, 0.94 and 0.97 as a fraction of the total variance, respectively for plant height, number of leaves, number of branches, number of nodes, fruit length and root length.

Provision of plastic mulches under summer okra cultivation, created favourable micro environment and enhanced plant growth parameters (Figure 3), which was evident from its association with the increased total fruit yield of okra. Regardless of the mulch type, mulching of soils was associated with a higher plant growth parameters and total okra yield as compared to control (without mulch).

The use of plastic mulch promoted changes in the microclimate of the plant, favouring growth and vigour production, and yield.

Relationship between microbial population and okra fruit yield

The co-relation, developed between microbial population and okra yield are presented in Figure 4. Different plastic mulches, favoured an increase in microbial population and fruit yield of okra, according to the type of plastic mulch. The highest microbial population was obtained when soil was mulched with the silver-black plastic mulch (Figure 4.).

Development of Multiple Regression Model

In order to remove effect of non-effective characteristics in regression model on okra fruit yield, stepwise regression analysis was used. Stepwise regression is a semi-automated process of building a model by successively adding or removing variables based solely on the t-statistics of the estimated coefficients.

To predict the fruit yield of okra, the data of fruit yield and other traits were subjected to statistical analysis using SPSS Statistics ver. 20.SPSS Statistics, a software package developed by SPSS Inc. Coefficient of determination (R^2) was calculated and tested for significance at 5% level of probability.

Multiple regression model for prediction summer okra fruit yield was developed using the following equation:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots + b_{10}X_{10}$$

Where,

$\hat{Y}$ = Predicted fruit yield of okra

b_0 = Intercept

b_1 = Regression coefficient for X_1 (1=n)

X_1 = Independent variable (1=1 n i.e. other traits)

Table.1 Monthly climatic data at the experiment site during growing season of summer 2017 and 2018

Month	Total Rainfall (mm)	Temperature (^{0}C)		Humidity (%)		EVP (mm)	BSS (Hrs./day)	WS (Kmph)
		Max	Min	RH_{AM}	RH_{PM}			
	Yr. 2017							
February	0.0	33.7	13.5	71.7	24.0	6.4	9.8	3.7
March	0.0	36.9	16.8	67.1	19.4	9.4	9.6	3.9
April	0.0	41.1	20.8	46.8	11.0	11.8	10.3	4.6
May	0.0	41.8	26.6	43.5	17.6	13.5	9.5	5.9
	Yr. 2018							
February	0.0	32.6	13.3	74.8	24.7	5.2	8.3	3.4
March	0.2	36.9	17.6	66.7	17.9	7.7	8.5	3.9
April	0.0	40.5	21.4	47.8	15.1	11.0	9.6	4.2
May	0.0	42.3	26.3	43.5	19.9	13.4	9.0	5.4

(Source: Department of Agricultural Meteorology, VNMKV, Parbhani, Maharashtra)

Figure.1 Relationship between mean soil moisture and fruit yield of okra under different plastic mulches

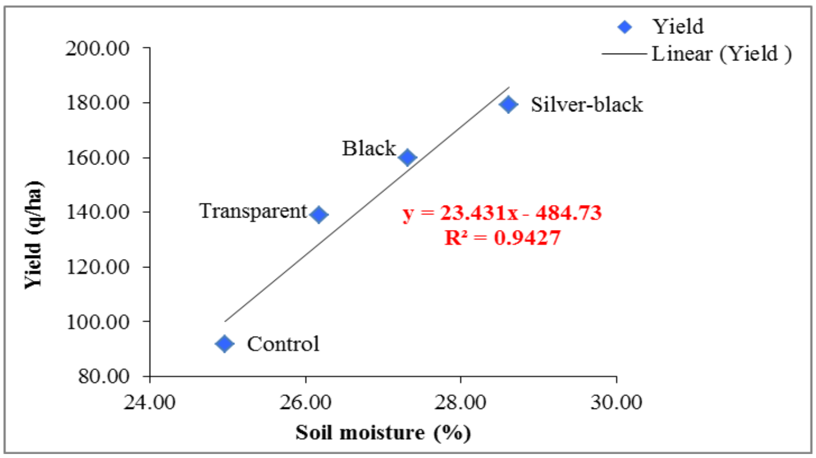

Figure.2 Relationship between mean soil temperature and fruit yield of okra under different plastic mulches

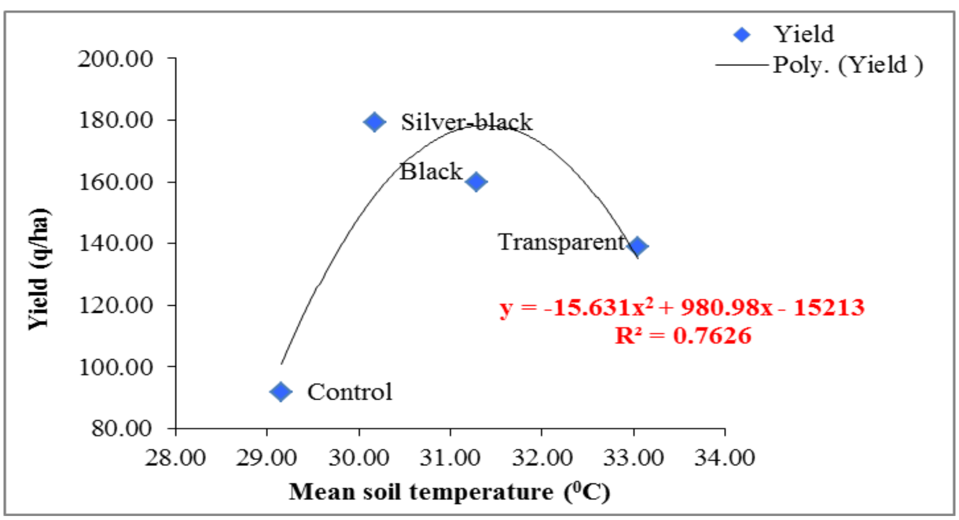

Figure.3 Relationships between plant growth parameters and fruit yield of okra

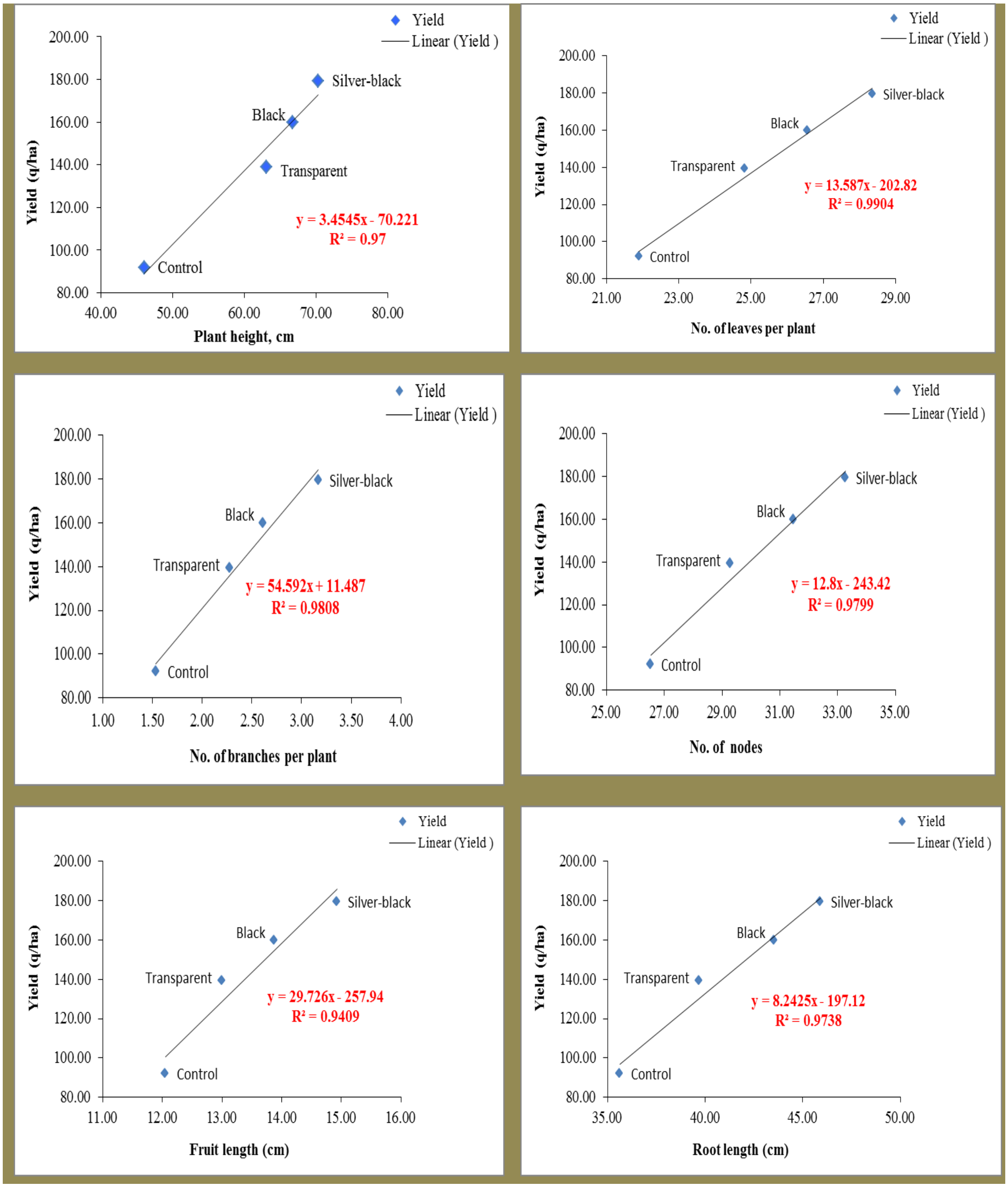

Table.2 Correlation relationship between okra fruit yield and growth parameters

Independent variable			Equation	R^2
Dependent variable: yield (q/ha.)				
Plant height (cm)	y	=	3.4545x – 70.221	0.97
No. of leaves per plant	y	=	13.587x – 202.82	0.99
No. of branches per plant	y	=	54.592x + 11.487	0.98
No. of nodes per plant	y	=	12.8x – 243.420	0.98
Fruit length (cm)	y	=	29.726x – 257.94	0.94
Root length (cm)	y	=	8.2425x – 197.12	0.97

Figure.4 Relationships between microbial population and fruit yield of okra

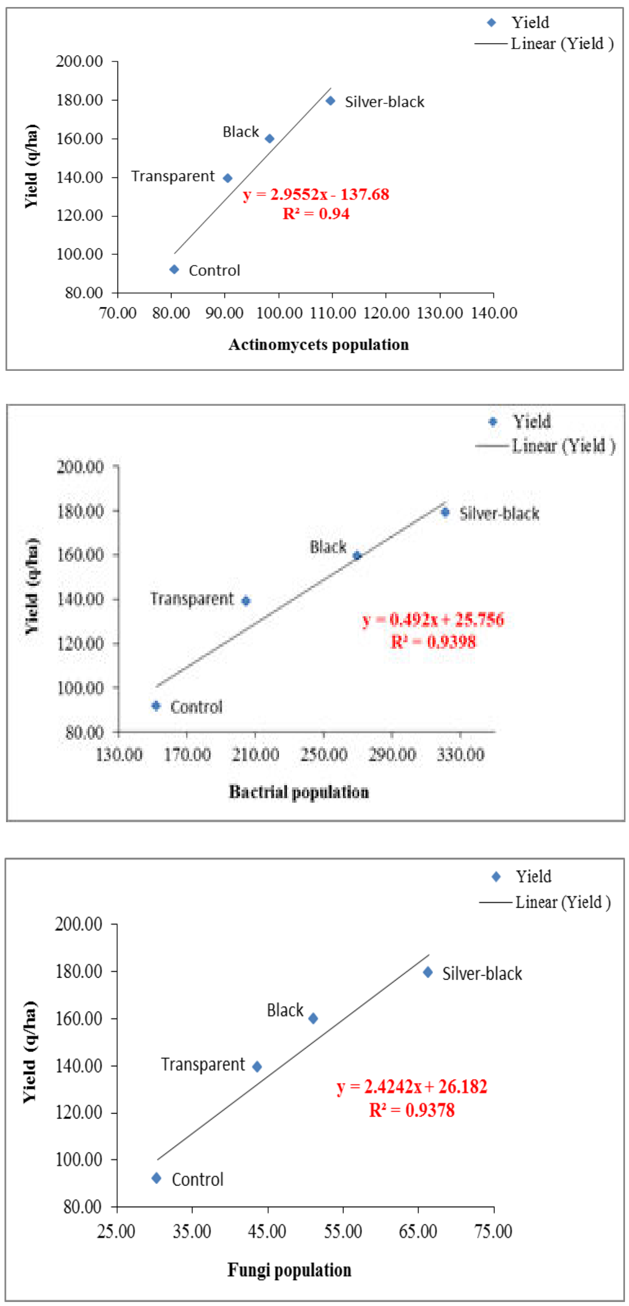

Table.3 Stepwise regression equation for prediction of okra fruit yield

Year	Regression equation (Stepwise)	R^2
2017	Y = -172.223+7.599*Root length	0.90
2018	Y = -155.335+0.464*Bacterial population + 5.907*Soil temperature	0.97
Pooled mean	Y = -134.094 + 4.317*Root length + 1.614*Plant height	0.93

The result of development of stepwise regression model for summer okra is presented in Table 3. Root length, bacterial population, soil temperature and plant height, influenced the maximum of yield change.

Based on the output from SPSS 20 software, for development of multiple regression model for summer okra fruit yield, indicated that among different parameters, okra plant root length and plant height were found to be more effective as yield predictors.

Y = -134.094 + 4.317*Root length + 1.614*Plant height, R^2= 0.93

Thus, the multiple regression model could be used for yield prediction of summer okra fruit yield.

Conclusions

Okra plant root length and plant height were found to be more effective as yield predictors for summer okra growing season. Thus the developed model could be used for yield prediction of okra yield.

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