International Journal of Plant & Soil Science

Volume 36, Issue 7, Page 508-516, 2024; Article no.IJPSS.118824
ISSN: 2320-7035

Evaluation of Strawberry (*Fragaria* × *ananassa* Duch.) under Rice Fallow as Influenced by Tillage, Stubble Mulch and Nutrient Management

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i74759

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/118824

Original Research Article

Received: 14/04/2024
Accepted: 17/06/2024
Published: 18/06/2024

ABSTRACT

Aims: The experiment was conducted to evaluate the effect of tillage, stubble mulch and nutrient on growth, yield and quality of strawberry.
Study Design: The experiment was conducted using a split plot design, with three main plots, four sub plots and three replications each.
Place and Duration of Study: The field experiment was conducted in ICR farm of Assam Agricultural University, Jorhat during winter season of 2021-22.

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Cite as: *Thakur, Vishal, Bornali Gogoi, Nilay Borah, and Himadri Shekhar Dutta. 2024. "Evaluation of Strawberry (Fragaria × Ananassa Duch.) under Rice Fallow As Influenced by Tillage, Stubble Mulch and Nutrient Management". International Journal of Plant & Soil Science 36 (7):508-16. https://doi.org/10.9734/ijpss/2024/v36i74759.*

Methodology: The experiment consists of 3 main plots each including (bed planting with rice stubble mulch, minimum tillage with rice stubble mulch and conventional tillage practice) and 4 sub plots having (10-7-7 g/m^2 N-P-K with 5 kg/m^2 FYM, 7.5-5-5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP, 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP and 200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP).

Results: The results revealed that bed planting with rice stubble mulch was superior over other tillage and mulch treatments in respect of vegetative growth, quality parameters and yield. Application of 200-20-2 (FYM-lime-wood ash) g/plant significantly resulted in maximum vegetative growth and yield. However, best quality parameters like highest TSS, sugars and low acidity were recorded in treatment having 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2.

Conclusion: From this experiment we concluded that bed planting with rice stubble mulch along with application of 200-20-2 (FYM-lime-wood ash) g/plant leads to maximum vegetative growth and yield in strawberry. And rice fallow and stubble mulch technique can be utilized for successful production of annual strawberry for higher return with minimum investment.

Keywords: Rice fallow; minimum tillage; rice stubble mulch; strawberry; vermicompost.

1. INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a popular fruit due to its nutritional properties and alleged health benefits and its production has increased steadily in recent decades. Strawberry belongs to *Rosaceae* family having chromosome number of 56 and botanically is an octaploid. The modern cultivated strawberry was created in France in the 18th century as a consequence of an accidental cross between two wild species, *Fragaria chiloensis* and *Fragaria virginiana*. In addition to possessing dessert-like qualities, it has low-calorie carbohydrate that is high in fiber and pectin, with a pectin content of 0.55 percent, vitamin A concentrations (60 IU/100 g) and ascorbic acid (30–120 mg per 100 g of edible part) [1]. Strawberries have a 90% water content, high levels of vitamin C, foliate, and phytochemical substances such ellagic acid found in the fruit, which lowers the chance of developing cancer (5–50%) and asthma [2-3]. Different minerals like phosphorus, potassium, iron, and calcium that are beneficial for human health are also present in fruit. Strawberry is traditionally grown in the country's temperate zone. However, it can be grown in a subtropical temperature and even at higher altitudes in a tropical climate, and it is propagated by one year old runners and through tissue culture methods [4-6].

In arable temperate regions of the world, strawberry is a low-growing herbaceous perennial with fibrous roots and a crown from which the basal leaves emerge. The leaves have a sawtooth edge, three leaflets, and are complex. Pelarogonidin 3-monoglucoside an anthocyanin, and trace amounts of cyanidin give the fruit its red colour [7]. The strawberry fruit is an aggregate fruit, botanically classified as etaerio of achenes. Fruit flavor is composed of three substances: sugar, acids, and aromatic chemicals. Ethyl esters, such as ethyl butanoate and ethyl hexanoate, are the main volatile compounds responsible for the fruit's flavour. Strawberry flavourings and scents are also frequently employed in a variety of products such as lip gloss, sweets, hand sanitizers, perfume, and many others.

In India total production strawberry is around 13.53 thousand tons in an area of around 3 thousand hectares (According to National Horticulture Board, 2021-22) [8]. In Assam 10.42 lakh ha of land is rice fallow land during *Rabi* season. There is significant potential for increasing the productivity of rice-based systems by incorporating short-duration crops into the existing cropping system during the rabi season. And this area can be utilized for cultivation of strawberry for increasing annual income of farmers. In India, 130 million tonnes of rice straw are produced each year, with over half of it going to waste. Even though rice straw is used as animal feed, in brick kilns, and in the paper and packaging sectors, the majority of farmers are unaware of its potential for recycling into manure or as a raw material for other industries. This stubble mulch material reduces evaporation and moderates significant daily temperature variations in the soil, especially in the root zone, making it suitable for use as a mulch in strawberry cultivation [9].

In recent decades, the notion that ploughing is essential for successful cropping has come under scrutiny. Minimum (conservative) tillage has grown in favor because of the need to lower production costs. There are many well-known advantages to crop rotation and using organic manures in conservation tillage [10-11]. Except for its benefit in lowering cultivation costs, minimum (conservation) tillage practices significantly improve the physical and chemical characteristics of soil when growing rice on fallow fields [12-13]. Concerns over preventing environmental pollution and ensuring food safety have grown in recent years. By using the optimum fertilizer, agronomical practices, and conservational tillage we can satisfy the requirements of sustainable crop production [14,15].

2. MATERIALS AND METHODS

The experiment was completed during 2021-22 at the Instructional cum Research (ICR) Farm, of Assam Agricultural University, Jorhat. The experimental field is situated 86.8 meters above mean sea level at 26°45'N latitude, 94°12'E longitude. The region has a subtropical climatic conditions having hot and humid summer followed by cold winter. The mean least and greatest temperature recorded during the time of study are 8.2°C and 33.3°C separately. The mean month to month relative humidity was fluctuated from 40.00 – 99.00 %. The experiment was conducted followed by the split-plot design with three main plot treatments (M_1= Bed planting with rice stubble mulch, M_2= Minimum tillage with rice stubble mulch and M_3= Conventional tillage), four sub plot treatments N_1= 10-7-7 g/m^2 N-P-K with 5 kg/m^2 FYM, N_2= 7.5-5-5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP, N_3= 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP and N_4= 200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP and three replications. The vermicompost used in treatments was incubated with biofertilizers like *Azospirillum* and *Azotobacter* @ (2g/kg) for 15 days.

Planting material consist of tissue cultured seedlings acquired by a certified nursery. Winter dawn variety was planted in well prepared field at a spacing of 45cm x 45cm and planting was done on November 23, 2021. Field consists of sandy clay loam soil with initial analysis of soil was recorded with pH 5.4, organic carbon 8.2g kg^{-1}, available N 166.7 kg ha^{-1}, available P_2O_5 9.2 kg ha^{-1} and available K^{2}O 127.5 kg ha^{-1}. The conventional tilled plot was tilled and harrowed manually and soil turned into fine tilth and minimum tillage plot was not disturbed until planting and small area of plot was tilled with ‘khurpi’ where seedling was planted. As all sub plots consists of different doses of fertilizers, in first sub plot (N_1) recommended amount of FYM was applied during field preparation along with half dose of nitrogen, full dose of phosphorus and full dose of potassium was applied during flowering period. And in the remaining sub plots mixture of fertilizer was applied in two split doses at 10 days and 30 days after planting of strawberry seedlings. Recommended plant protection measures were also adopted for controlling pests and diseases at various stages of growth.

Vegetative growth and yield parameters *viz.,* Plant height (cm), number of leaves, diameter of crown (mm), days to first flowering, number flowers per plant, number of fruits per plants, fruit weight (g), fruit set percentage and fruit yield were recorded. Five plants from every treatment in every replication is chosen for taking readings. Quality parameters, viz., Total Soluble Solids (TSS), titratable acidity, ascorbic acid content, total sugar and reducing sugars were also recorded from fully ripe fresh fruits. Each plant’s berries were crushed, and the juice was extracted by pressing the pulp through muslin cloth. Soil parameters, viz., pH of the soil, moisture content, organic carbon, available N, P and K were recorded from soil samples taken after harvest of whole produce.

3. RESULTS AND DISCUSSION

Different tillage, mulching and nutrient management practices exhibited significant effect on growth, yield and quality parameters of strawberry plant.

3.1 Height of Plant

Plant height was significantly influenced due to various tillage and nutrient management practices. Highest plant height of (18.26 cm) was observed in bed planting with rice stubble mulch in main plot. It could be due to regulation of soil temperature by forming a buffer layer on soil surface [16], helps in better development of fine roots in upper strata of the soil rich in oxygen [17]. This could have expanded the absorption of water and supplements from the soil leading to better growth. Similar result of increase in plant height were given by Ali and Gaur [18] in

strawberry. Table 1 also revealed that in sub plot plant height was significantly influenced due to nutrient management practices, maximum plant height of (18.81 cm) was observed in treatment combination of 200-20-2 (FYM-lime-wood ash) g/plant. Similar results were observed in treatment combination of 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP having plant height of (18.21cm). The expansion in height may be because of the accessibility of nutrients that could have agreed the plant need.

3.2 Number of Leaves

Maximum number of leaves (18.18) were observed with bed planting with rice stubble mulch in main plot and in case of sub plot treatment 200-20-2 (FYM-lime-wood ash) g/plant gave maximum leaves number of (18.73). The larger number of leaves in mulched plots may be due to better root development as compared to minimum tillage plot. Thus, better root system leads to better absorption of nutrient leading to larger growth of plant. The results were similar with Das et al. [19]. And due to better uptake of nutrients due to combination of FYM and lime at shown by Behera et al. [20] in maize and pH of soil was also increased due to this treatment with may lead to more nutrient availability and better growth of plants.

3.3 Crown Diameter

Data presented in Table 1 shows that maximum crown diameter of (54.77 mm) was observed in bed planting with rice stubble mulch in main plot and in case of sub plot maximum crown diameter of (52.53 mm) was observed in treatment 200-20-2 (FYM-lime-wood ash) g/plant. Similar growth parameters were also recorded in treatment combination of 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2. Superior growth of crown in these both treatments as compared to other treatments may be due to better nutrient availability and uptake of macro and micro nutrients by plants. And better availability of phosphorus due application of FYM+ Lime [21].

3.4 Days to First Flowering

Days to first flowering is an important parameter to judge the early fruiting habit of plant. The minimum number of days taken for first flowering was recorded in minimum tillage with rice stubble mulch and maximum days were observed in conventional tillage. The early flowering may be due to accumulation of more heat units under minimum till conditions and in case of rice stubble mulching flowering initiation was delayed due to low temperature of soil. Sinkevičienė et al. [22] showed similar findings. The treatment having 200-20-2 (FYM-lime-wood ash) g/plant leads to minimum (62.26) days to first flowering. Addition of biofertilizer with vermicompost leads to early flower initiation [23].

3.5 Number of Flowers and Fruits per Plant

The maximum number of flowers (17.03) and maximum fruits per plant of (13.86) were present in bed planting with rice stubble mulch. And in subplot maximum number of flowers per plant (17.59) and fruits per plant (14.35) was present in nutrient combination of 200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP (as instant mixture). Minimum number of flowers per plant (13.72) in 7.5-5-5 g/m2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture). The increase in number of flowers in N_4 may be due to supply of optimum level of nutrients availability due to increase in pH of soil and leading for favourable soil conditions for strawberry.

3.6 Fruit Weight and Fruit Set Percentage

The bed planting with rice stubble mulch reported the maximum fruit weight of (26.08) grams and fruit set percentage of (80.94%). And the least weight of (21.10 g) was observed in minimum tillage with rice stubble mulch. The fruit weight was greatest in plants stubble mulch because of creation of more photosynthates, regulation of soil temperature, suppression of weed growth and continued supply of water, nutrients and in light of the fact that the same treatment recorded the greater number of leaves and vigorous plant canopy all through the yield development period and furthermore because of better soil conditions leading to high availability of nutrients and apportioning of photo assimilates. Maximum amount of fruit weight (27.40 g) and fruit set (83.94%) was observed in was recorded in [5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture)]. Increase in weight in M_3 might be additionally ascribed to better fillings of fruits because of more balanced take-up of supplements which may have prompted better metabolic activities in the plant. The applied N, P, K and biofertilizers in mixture with vermicompost were used productively by the plant, which brought about delivering most extreme photosynthates in terms of high biomass and movement of acclimatizes to the developing fruit resulting in higher fruit weight [24].

Table 1. Growth and yield parameter of crop

Treatments	Plant Height (cm)	Number of Leaves	Crown Diameter (mm)	Days to First Flowering	Flower Per Plant	Number of Fruits Per Plant	Fruit Weight (g)	Fruit Set Percentage (%)	Yield Per Plant (g)
Tillage and Mulching Practices									
M_1	18.26	18.18	54.73	62.96	17.03	13.86	26.08	80.94	368.78
M_2	15.83	14.98	45.18	60.02	14.75	11.25	21.10	76.05	241.76
M_3	17.54	17.20	51.21	71.44	15.07	11.97	23.15	79.25	282.06
CD (0.05)	1.57	1.19	3.80	3.47	0.65	0.88	0.82	2.41	32.43
Nutrient Management									
N_1	16.17	15.72	51.20	68.97	15.27	11.73	21.82	76.53	259.83
N_2	15.65	15.06	45.62	66.81	13.72	10.01	19.33	72.93	198.12
N_3	18.21	17.63	52.28	63.95	15.88	13.35	27.40	83.94	365.80
N_4	18.81	18.73	52.53	62.26	17.59	14.35	26.10	81.58	375.53
CD (0.05)	0.64	0.77	2.24	2.01	0.80	0.63	0.95	2.22	18.98
Interaction (M x N)	1.35	NS	4.44	NS	1.45	1.22	NS	NS	37.63

3.7 Fruit Yield per Plant

Different tillage and mulching practices influenced significantly the yield of strawberries. The maximum yield of (368.78 g) per plant was observed in treatment having bed planting with rice stubble mulch. And minimum yield per plant of (241.76 g) in minimum tillage with rice stubble mulch. The higher yield in stubble mulched treatment was due to higher number of fruits per plant and larger fruit weight which was a result of higher soil moisture, regulated soil temperature, concealment of weed development and continuous supply of water, macronutrient, micronutrient and photo assimilates during the plant growth phase. Das [19] reported similar results in yield of tomato by rice stubble incorporation.

The maximum yield of 374.53 grams per plant was found in [200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP (as instant mixture)]. The yield parameters of fruits are determined by its vegetative development all through the life cycle of the plant and both these treatments developed vigorous vegetative growth. It might be due to better pH condition in soil better root proliferation. Resulting in expanded nutrient components in the soil, improved take-up of nutrients and water caused to higher photosynthesis prompting an expansion in final yield.

3.8 Total Soluble Solids, Reducing Sugar and Total Sugar

The maximum amount of Total soluble solids (TSS) 7.88 °B, reducing sugars (5.63 %) and total sugars (6.38 %) was observed in bed planting with rice stubble mulch. This might be due to continuous supply of photo assimilates and nutrients under mulched conditions. The maximum TSS of 8.16 °B, reducing sugar of 5.79 % and total sugars of 6.71 % were recorded in 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture) (Table 2). The increase in TSS and total sugars may be due to combined effect of biofertilizers and optimum nitrogen application by combination of chemical fertilizers and vermicompost. Absorption of nitrogen might play good part as a significant constituent of endogenous elements in influencing the nature of fruit in which sugar is significant. Similar results due to application of 50 % NPK, vermicompost and biofertilizers was reported by Singh [25,26].

3.9 Titratable Acidity and Ascorbic Acid

The minimum acidity content of 0.54% was recorded in bed planting with rice stubble mulch (Table 2). And maximum acidity content of 0.72% in conventional tillage treatment. The maximum ascorbic acid of (50.45) was present in treatment having minimum tillage with rice stubble mulch. The minimum acidity content of 0.53% was observed in treatment having [5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture)] and the maximum ascorbic acid of (51.38) was recorded in treatment having 7.5-5-5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture).

The decrease in titratable acidity might be ascribed to the transformation of the natural acids and photosynthates into sugar during fruit maturation due to biofertilizers [27]. The higher ascorbic acid substance may be because of impact of biofertilizers which could expand the pace of biosynthesis of ascorbic acid from its forerunner glucose 6 phosphate which might improve the ascorbic acid substance. Results were similar to observations of Ayesha et al. [28] and Dar et al. [29] in strawberry.

3.10 Soil pH

The maximum pH of 5.71 was recorded in bed planting with rice stubble mulch and under nutrient management maximum pH value of 5.95 was recorded in treatment having 200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP (as instant mixture) (Table 3). Due to incorporation of rice straw in soil higher LAP (Leucine amino peptidase) was observed and its ability to increase soil pH was reported by Li et al. [30]. The increased soil pH in N_4 might be due to application of lime. The release of basic cations, particularly Ca^{2+} and Mg^{2+}, in response to the pH differences among organic additions may have neutralised acid during microbial decarboxylation [31].

3.11 Soil Carbon and NPK after Harvest

The maximum organic carbon content of (8.55g/kg) was observed in bed planting with rice stubble mulch. It may be due to decomposition of rice stubble mulch with time leading to increase in organic content of soil (Table 3). The amount of available nitrogen, available phosphorus and available potassium due to tillage and mulching practices was found to be non-significant. The

Table 2. Quality parameters of fruit

Treatments	TSS (°Brix)	Reducing Sugar (%)	Total Sugar (%)	Titratable Acidity (%)	Ascorbic Acid (mg/100g)
Tillage and Mulching Practices					
M_1	7.88	5.63	6.38	0.54	49.01
M_2	7.61	5.37	6.25	0.57	50.45
M_3	7.51	5.23	6.15	0.72	47.06
CD (0.05)	0.21	0.13	0.04	0.08	1.85
Nutrient Management					
N_1	7.59	5.21	5.95	0.69	46.22
N_2	7.80	5.53	6.47	0.57	51.38
N_3	8.16	5.79	6.71	0.53	50.03
N_4	7.13	5.12	5.88	0.64	47.75
CD (0.05)	0.41	0.10	0.17	0.08	1.70
Interaction (M x N)	0.73	NS	NS	NS	NS

Table 3. Soil parameters

Treatment	pH	Organic Carbon (g/kg)	Available Nitrogen (kg / ha)	Available Phosphorus (kg / ha)	Available Potassium (kg / ha)
Tillage and Mulching Practices					
M_1	5.71	8.55	168.87	9.80	128.90
M_2	5.56	8.36	167.96	9.74	128.10
M_3	5.46	8.13	167.08	9.50	127.90
CD (0.05)	0.21	0.19	NS	NS	NS
Nutrient Management					
N_1	5.28	8.47	167.10	9.58	129.80
N_2	5.48	8.42	167.44	9.89	129.20
N_3	5.66	8.30	166.87	9.91	131.20
N_4	5.95	8.22	166.91	9.81	130.66
CD (0.05)	0.27	NS	NS	NS	NS
Interaction (M x N)	NS	NS	NS	NS	NS

organic content of soil, available nitrogen, available phosphorus and available potassium due to nutrient management practices and interaction between tillage and nutrient management was found to be non-significant [32].

4. CONCLUSION

Finally, based on the findings we can conclude that, treatment combination of bed planting with rice stubble mulch along with 200-20-2 (FYM-lime-wood ash) g/plant in equal split at 10 and 30 DAP (as instant mixture) gave maximum growth attributes, yield and highest monetary returns. And bed planting with rice stubble mulch along with 5-3.5-3.5 g/m^2 N-P-K + vermicompost 200g/m^2 in equal split at 10 and 30 DAP (as instant mixture) found to be suitable for best quality fruits. Furthermore, it is possible to use mulch made of rice stubble and conservative tillage techniques, such as minimum and zero tillage, in horticultural crops to produce food in a sustainable manner.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Available:https://doi.org/10.9734/ajaar/2024/v24i1485.

Peer-review history:
The peer review history for this paper can be accessed here:
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