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Research Article
Effectiveness of Sawdust Mulch and NPK (15:15:15) Fertilization on Pepper (*Capsicum annum* L.) Production

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Abstract

Background and Objective: Sawdust is infrequently used as a mulch material because of its undesirable effects on crops like yield reduction. Combined use of sawdust mulch and inorganic fertilizer may help to overcome this problem. This study evaluated the growth and yield responses of pepper to sawdust mulch and NPK 15:15:15 fertilizer rates (0, 150, 300 and 450 kg ha^{-1}) applied sole and in combination with sawdust. **Materials and Methods:** About 3 weeks old pepper seedlings were transplanted into poly pots containing 10 kg of soil. The NPK fertilizer was applied to the potted plants 14 days after transplanting (DAT) while sawdust mulch was placed around the seedlings at 28 DAT in layers of 5 cm thickness. The experiment was laid in completely randomized design with 6 replications. Data collected were analyzed using ANOVA at 5% probability level. **Results:** Combined use of sawdust mulch and NPK fertilizer increased significantly growth and yield of pepper compared to when either the mulch or the fertilizer was applied sole. Increasing the fertilizer above 300 kg ha^{-1} in both sole and in combination with mulch caused significant decrease in yield. Pepper yields were 21.4, 37.8, 44.4-70.1, 80.9-111.0 g/plant in the control, mulched, NPK and mulched plus NPK, respectively. **Conclusion:** The results obtained in this study showed that maximum pepper production can be achieved by combined use of sawdust mulch plus 300 kg ha^{-1} NPK 15:15:15 fertilizer.

Key words: Sawdust mulch, fertilizer rates, yield response, pepper production, NPK

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pepper (*Capsicum annum*) is a crop in the Solanaceae family[1]. It is a very important fruit vegetable in the tropics and the world's second most important vegetable after tomatoes[2]. *Capsicum* fruits are consumed fresh, dried or processed as vegetable and as spice or condiments. It is an indispensable part of daily diet of millions of Nigerians. Pepper is a rich source of vitamin A, C and E. It is reported that both hot and sweet peppers contain more vitamin C than any other vegetable crops[1]. Dried seeds of pepper contain 2% volatile oil, which is used in sausages and table sauces[3]. Peppers have also been reported to have medicinal value. They are presently the most recommended topical medication for arthritis[4].

Pepper plants have a shallow root system. In Nigeria, the bulk production of pepper is found in the drier savanna zone and derived savanna area of the south western Nigeria[5]. Hence, the use of an organic soil cover is very beneficial in its production[3]. The use of organic mulches as soil cover provides a good relationship between soil, water and plant[6] and profits plant growth by reducing water loss by evaporation, thus conserving soil moisture, acting as a barrier to rainfall, which causes soil compaction and erosion and suppressing weed[7,8]. These changes in the soil environment are excellent for crop growth and stronger roots; consequently increased absorption of soil water and nutrients[7].

Various materials are utilized as mulch and these include weed or grass clippings, paddy straw, bark, sawdust and plastic. The use of black polythene straw and water hyacinth as mulched materials was reported to significantly increase growth and yield of garlic compared to the control[9]. Bottle gourd mulched with straw was found to produce higher number of primary branches in comparison with the bare plant[10]. There is also report of yield improvement of chilli plant in sawdust mulched soil compared to un-mulched[11]. Higher crop yield has been reportedly observed by combined use of mulch and inorganic fertilizer. For instance, highest bulb yield of onion was found when straw mulch was combined with N and K fertilizers[12]. Also, higher growth and yield of okra was reported under mulch plus inorganic fertilizer[8].

However, sawdust mulch have been reported to have negative effects on crops owing to its high C: N[13]. This may be overcome by integrated use of sawdust mulch and inorganic fertilizer. Therefore, the experiment was aimed at determining the effects of sawdust mulch and NPK fertilizer on the growth and yield of pepper.

MATERIALS AND METHODS

Study location: The experiment was conducted at the botanical garden of Plant Science and Biotechnology Department, Abia State University, Uturu, Nigeria, located at latitude 7°6′North and longitude 6°0′East. The experiment lasted for 3½ months (August-November, 2017).

Sources of materials: Pepper seeds used for this work were sourced from National Horticultural Research Institute (NIHORT), Mbato sub-station, Okigwe, Imo state, Nigeria. The saw dust was collected from a timber market in Okigwe, Imo State while the NPK fertilizer was sourced from Agricultural Development Programme, Umuahia, Abia State.

Raising of seeds in the nursery: The pepper seeds were raised in nursery beds. A portion in the botanical garden was cleared, the soil was worked on and seed bed of 1 m^2 made. The seed bed was watered after which the pepper seeds were broadcasted on the seed bed and lightly covered with soil.

Transplanting of pepper seedlings: The experiment was conducted in poly pots. About 10 kg of soil was weighed into poly pots and the soil watered. Three weeks old pepper seedlings were transplanted into the poly pots containing 10 kg of soil. The pots were properly labeled according to the treatment combinations for proper data collection.

Experimental design: The experiment was arranged in a completely randomized design with eight treatments each replicated six times. The treatments were mulched and un-mulched soil and four levels-0, 150, 300 and 450 kg ha^{-1} of applications of NPK (15:15:15) fertilizer. These treatments were combined together to give a total of eight treatment combinations-un-mulch+0 kg ha^{-1} NPK which served as the control, mulch, 150 kg ha^{-1} NPK, 300 kg ha^{-1} NPK, 450 kg ha^{-1} NPK, mulch+150 kg ha^{-1} NPK, mulch+300 kg ha^{-1} NPK and mulch+450 kg ha^{-1} NPK.

Treatment application: The NPK fertilizer was applied to the potted plants 14 days after transplanting (DAT) according to the treatments using the ring method while sawdust used as the mulch material, was placed around the seedlings at 28 DAT in layers of 5 cm thickness in the respective pots.

Data collection: Data were collected for the following:

- **Plant height:** This was measured with a meter rule from the base of the stem at soil level to the terminal bud of the main stem at weekly interval from 35-63 days after transplanting (DAT)

- **Number of leaves:** The number of leaves produced per pepper plant was counted and the mean value recorded. This was done at weekly interval beginning from 35-63 DAT
- **Number of branches:** The number of branches produced per pepper plant was also counted and the mean value recorded at weekly interval from 35-63 DAT
- **Leaf area:** This was calculated using the planimetry method described already[14]. The leaf shapes were traced on graph sheets of one square centimeter. The number of squares covered by the leaf shape and the squares which have been divided by the leaf margin by at least half were counted and recorded as the leaf area. This was done at weekly interval from 35-63 DAT
- **Root length:** For this measurement, the potted medium was carefully torn; the pepper seedling with the soil attached was put in a bucket of water to remove the soil particles adhering to it. It was rinsed in water and allowed to drain. The length was then measured with a meter rule from the base of the root to the root tip. This was done at 63 DAT
- **Dry weight:** The plants used for root measurement were also used for determination of the dry weight. After the measurement of the root length, the plants were chopped into pieces, packaged separately in properly labeled envelopes and then oven-dried at a temperature of 80°C until a constant weight was achieved. Thereafter, they were weighed separately using an electronic top loading balance
- **Number of fruits:** Pepper fruits produced per plant was harvested as the fruits mature, counted and the value recorded as the number of fruits.
- **Fresh fruit weight:** At each harvest, the fruits were weighed after counting using an electronic top loading balance and the weight recorded

Data analysis: All data collected were subjected to one way analysis of variance (ANOVA) and significant means partitioned using Fishers' Least Significant Difference at probability level of 0.05.

RESULTS

Plant height: Significant differences ($p<0.05$) were found among the treatments on plant height of pepper in all the sampled days with the exception of 35 DAT (Table 1). Sole application of NPK fertilizer at 150 kg ha^{-1} significantly increased plant height of pepper in relation to the control and mulched plants from 49 DAT. The control and mulched plants had statistically similar plant heights. However, pepper plants mulched with sawdust plus NPK fertilizer at higher rates of 300 and 450 kg ha^{-1} consistently had statistically similar plant height values that were significantly higher than the other treatments.

Number of leaves: Effects of treatments on number of leaves produced by the pepper plants became significant ($p<0.05$) from 49 DAT (Table 2). Control and the mulched plants produced number of leaves that were not significantly different but were significantly lower than the other treatments. Plants that received sole applications of NPK produced number of leaves that were statistically similar. In all the sampled periods, plants in mulched plus 300 kg ha^{-1} NPK produced significantly the highest number of leaves. Increasing the rate of NPK application above 300 kg ha^{-1} in mulched plants lead to significant decrease in the number of leaves.

Number of branches: Number of branches produced by the pepper plants was found to vary significantly ($p<0.05$) among the treatments in all the sampled periods (Table 3). Mulched plants consistently produced the least number of branches, although the values were not statistically different from those of the control. However, sole applications of NPK fertilizer did not result in any significant increase in the number of branches in relation to the control. At 49 DAT, combination of mulch plus 300 kg ha^{-1} NPK recorded number of branches that were comparable with the other combinations but significantly higher than their sole applications and also the control. At other sampled days, combined use of mulch plus 300 kg ha^{-1} NPK recorded number of branches that was statistically similar to the other combinations and also to sole applications of NPK fertilizer but significantly higher than the control and mulch alone.

Leaf area: Aside 49 and 56 DAT, significant effects of treatments on leaf area of pepper were found in the sampled days (Table 4). At 42 DAT, combined use of mulch plus 300 kg ha^{-1} NPK increased significantly leaf area in comparison with their sole applications and the control. By 63 DAT, sole applications of NPK and combined applications of mulch plus NPK fertilizer gave comparable leaf area values that were significantly greater than the control and mulch alone. In all the sampled period, the control plants had the least leaf area although it was not significantly different from that of the mulched plants.

Table 1: Effect of mulch and NPK fertilizer on plant height (cm) of pepper

	Days after transplanting (DAT)				
Treatments	35	42	49	56	63
Control	8.90	10.00^{cd}	11.08^{cd}	11.72^{c}	12.75^{c}
Mulch	8.33	9.50^{d}	10.42^{d}	11.50^{c}	12.33^{d}
150 kg ha^{-1} NPK	11.25	11.95^{bc}	13.00^{b}	13.92^{b}	14.83^{b}
300 kg ha^{-1} NPK	10.25	11.33^{bcd}	12.42^{bc}	13.50^{bc}	14.42^{bc}
450 kg ha^{-1} NPK	9.33	10.25^{cd}	11.17^{cd}	12.33^{bc}	13.50^{bcd}
Mulch+150 kg ha^{-1} NPK	11.62	12.66^{b}	13.50^{b}	14.33^{b}	15.33^{b}
Mulch+300 kg ha^{-1} NPK	14.17	15.33^{a}	16.33^{a}	17.33^{a}	18.35^{a}
Mulch+450 kg ha^{-1} NPK	14.50	15.58^{a}	16.50^{a}	17.42^{a}	18.50^{a}
$LSD_{0.05}$	NS	2.12	1.90	2.01	2.04

NS: Not significant, means followed by the same letter in the same column are not significantly different according to fisher's LSD

Table 2: Effect of mulch and NPK fertilizer on number of leaves of pepper

	Days after transplanting (DAT)				
Treatments	35	42	49	56	63
Control	9.50	12.33	15.67^{de}	18.17^{d}	20.67^{e}
Mulch	8.83	11.66	14.67^{e}	17.67^{d}	21.33^{e}
150 kg ha^{-1} NPK	10.17	13.67	17.00^{cd}	22.00^{c}	23.83^{d}
300 kg ha^{-1} NPK	11.67	15.17	18.33^{bc}	21.83^{c}	24.83^{cd}
450 kg ha^{-1} NPK	12.00	15.83	18.50^{bc}	21.33^{c}	25.17^{cd}
Mulch+150 kg ha^{-1} NPK	10.83	16.67	19.50^{b}	23.17^{b}	26.17^{bc}
Mulch+300 kg ha^{-1} NPK	13.83	19.67	22.83^{a}	27.67^{a}	30.67^{a}
Mulch+450 kg ha^{-1} NPK	12.33	16.17	20.00^{b}	23.17^{b}	27.50^{b}
$LSD_{0.05}$	NS	NS	2.48	1.09	2.11

NS: Not significant, means followed by the same letter in the same column are not significantly different according to fisher's LSD

Table 3: Effect of mulch and NPK fertilizer on number of branches of pepper

	Days after transplanting (DAT)				
Treatments	35	42	49	56	63
Control	1.33^{bc}	1.50^{bc}	1.50^{cd}	2.17^{bc}	2.67^{c}
Mulch	0.66^{c}	0.66^{c}	1.00^{d}	1.33^{c}	1.66^{d}
150 kg ha^{-1} NPK	1.83^{abc}	2.33^{abc}	3.00^{bc}	3.33^{abc}	4.33^{bcd}
300 kg ha^{-1} NPK	2.00^{ab}	2.33^{abc}	2.67^{bcd}	4.00^{ab}	5.00^{abc}
450 kg ha^{-1} NPK	2.33^{ab}	2.50^{ab}	2.83^{bc}	3.67^{abc}	5.33^{abc}
Mulch+150 kg ha^{-1} NPK	2.33^{ab}	2.83^{ab}	3.67^{ab}	4.33^{ab}	6.00^{ab}
Mulch+300 kg ha^{-1} NPK	2.83^{a}	3.67^{a}	4.83^{a}	5.33^{a}	7.67^{a}
Mulch+450 kg ha^{-1} NPK	2.59^{ab}	2.83^{ab}	3.33^{ab}	4.83^{a}	7.00^{ab}
$LSD_{0.05}$	1.31	1.70	1.68	2.44	3.03

Means followed by the same letter in the same column are not significantly different according to fisher's LSD

Table 4: Effect of mulch and NPK fertilizer on leaf area (cm^2) of pepper

	Days after transplanting (DAT)				
Treatments	35	42	49	56	63
Control	32.08^{c}	44.83^{d}	81.68	92.90	101.43^{b}
Mulch	40.13^{c}	50.90^{cd}	80.38	98.33	106.98^{b}
150 kg ha^{-1} NPK	46.32^{bc}	62.87^{bcd}	89.77	100.28	155.43^{a}
300 kg ha^{-1} NPK	60.66^{ab}	71.70^{bc}	94.20	101.48	144.03^{a}
450 kg ha^{-1} NPK	60.98^{ab}	64.37^{bcd}	92.53	126.78	139.03^{a}
Mulch+150 kg ha^{-1} NPK	57.72^{b}	78.90^{ab}	100.95	121.83	151.02^{a}
Mulch+300 kg ha^{-1} NPK	74.70^{a}	99.70^{a}	116.57	149.82	157.42^{a}
Mulch+450 kg ha^{-1} NPK	62.49^{ab}	81.83^{ab}	104.58	128.12	147.61^{a}
$LSD_{0.05}$	16.58	23.41	NS	NS	31.37

NS: Not significant, means followed by the same letter in the same column are not significantly different according to fisher's LSD

Table 5: Effect of mulch and NPK fertilizer on root length, dry weight, number of fruits and fresh fruit weight of pepper at maturity

Treatments	RL (cm)	DW (g/plant)	NF/plant	FFW (g/plant)
Control	16.1^{bc}	3.0^{g}	5.3^{e}	21.4^{g}
Mulch	15.5^{c}	5.4^{f}	10.5^{de}	37.8^{f}
150 kg ha^{-1} NPK	19.7^{abc}	10.5^{bc}	13.4^{cd}	44.4^{ef}
300 kg ha^{-1} NPK	21.3^{ab}	9.0^{cd}	19.1^{bc}	70.1^{cd}
450 kg ha^{-1} NPK	18.0^{abc}	7.8^{de}	17.8^{bc}	56.7^{de}
Mulch+150 kg ha^{-1} NPK	20.1^{abc}	6.3^{ef}	22.6^{ab}	80.9^{bc}
Mulch+300 kg ha^{-1} NPK	21.5^{a}	11.4^{ab}	28.5^{a}	111.0^{a}
Mulch+450 kg ha^{-1} NPK	21.8^{a}	12.9^{a}	22.0^{b}	86.2^{b}
$LSD_{0.05}$	5.2	1.5	6.4	14.8

RL: Root length, DW: Dry weight, NF: Number of fruits, FFW: Fresh fruit weight, means followed by the same letter in the same column are not significantly different according to fisher's LSD

Root length: Application of NPK fertilizer at any rate recorded comparable root lengths with the control but significantly ($p<0.05$) longer root lengths than the mulched (Table 5). In the same vein, combined use of mulch plus NPK fertilizer rates had comparable root lengths with sole applications of NPK fertilizer rates. However, combination of mulch plus NPK fertilizer at 300 or 400 kg ha^{-1} resulted in significantly longer root length than the control and mulch alone, which on the other hand had statistically same root length values.

Dry weight: Significant effects of treatments were observed in the dry weight of the plant (Table 5). Combined application of mulch plus NPK fertilizer at 450 kg ha^{-1} recorded dry weight value that was similar to that of mulch plus 300 kg ha^{-1} but significantly higher than those of the other treatments. Control plants recorded significantly the least dry weight value. Sole application of NPK fertilizer at the rate of 450 kg ha^{-1} caused significant reduction in dry weight of the plant compared to the lower rate of 150 kg ha^{-1}.

Number of fruits: Sole application of NPK fertilizer at 300 or 450 kg ha^{-1} significantly increased the number of pepper fruits in comparison with the control and mulch alone (Table 5). Number of fruits produced by the control, mulch alone and sole NPK rate of 150 kg ha^{-1} were at par. However, combined use of mulch plus 300 kg ha^{-1} NPK resulted in significantly higher number of fruits in comparison with the other treatments with the exception of mulch plus 150 kg ha^{-1}.

Fresh fruit weight: Increasing the application of NPK fertilizer from 0-300 kg ha^{-1} increased significantly the fresh fruit weight of pepper (Table 5). Further increase to 450 kg ha^{-1} significantly decreased yield. Similarly, mulching increased significantly the fresh fruit weight of pepper in relation to the control. Furthermore, mulch plus 300 kg ha^{-1} NPK produced significantly ($p<0.05$) the highest fruit weight. This was closely followed by mulch plus 450 kg ha^{-1} NPK which had comparable fruit weight value with mulch plus 150 kg ha^{-1} NPK and the least was the control.

DISCUSSION

The results indicated that mulching with sawdust had no significant effect on the vegetative growth of pepper which included the plant height, number of leaves, number of branches and root length. However, significant improvement in yield was found due to the use of sawdust mulch. The non significant effect of sawdust mulch on growth characteristics of pepper may be attributed to the high C:N of sawdust[13,15], which resulted in slow decomposition or mineralization rate, slow nutrient release pattern and immobilization of nitrogen[16]. These results are in agreement with a researcher who found non-significant effect of sawdust mulch on pepper growth (plant height and number of leaves) but significantly higher yield in sawdust mulched pepper plants compared to the control[11]. The results are also in consonance with the report of other scientist who found non-significant effect of dry banana leaves, dry vetiver-grass and plastic mulch on growth of hot pepper[17]. The use of mulch material to improve yield had been widely reported in a number of crops[12,18-21]. Organic mulches when used as soil cover create a favorable soil, water and plant relationship[6], which is vital to plants as it reduces water loss by evaporation and conserves soil moisture[8]. The use of sawdust mulch therefore, was beneficial in conserving and maintaining high moisture content, which accounted for the higher yield recorded in mulched plants compared to the un-mulched[21,22].

Significant improvements in growth and yield of pepper in response to NPK fertilization were found. This result is in line with the findings of other researchers[23-25]. In many cases, application of NPK fertilizer above 150 kg ha^{-1} did not result in significant increase in the vegetative growth of pepper.

However, application above 300 kg ha^{-1} NPK caused significant decrease in yield and yield components of pepper. This is an indication that 150 and 300 kg ha^{-1} NPK fertilization were sufficient enough for plants uptake during the growth and reproductive stages, respectively. Beyond these rates, the plants will have luxury consumption of the nutrients, which will no longer be beneficial and may even be toxic to the plants leading to significant reduction in crops productivity. Similar assertion was made in a study on the effect of mulch type and NPK fertilizer rates (0, 60, 120 and 180 kg ha^{-1}) on cabbage where it was observed that application of fertilizer at 180 kg ha^{-1} retarded growth and yield of cabbage[22]. Similarly, in a different study, it was observed that increasing the rate of NPK fertilizer application above 120 kg ha^{-1} showed some negative effects on pepper such as; reduction in number of fruit set per plant, number of fruit harvested per plant, fresh fruit length per plant, 100 fruit weight and marketable fruit weight[23]. The higher NPK fertilizer rate required for optimal improvement in pepper yield indicated that larger quantity of nutrients was needed by pepper plants during the reproductive stage than the vegetative stage. This is in support of a researcher who reported that the greatest requirement for N, P and K in pepper is during the period of reproductive growth[26].

Highest improvements in growth and yield of pepper were recorded with combined use of sawdust mulch plus NPK fertilizer at the rate of 300 kg ha^{-1}. This showed that there was positive as well as significant synergy between sawdust mulch and NPK fertilizer application. Similar results of best improvements in growth and yield of crops grown under mulched plus inorganic fertilizer had been reported by Bhutia *et al.*[8] and Islam *et al.*[12]. Sawdust being an organic material served both as a mulched material and also as a source of nutrients to the crop upon decomposition[18,23]. On the whole, percentage increases in yield were 37.8, 44.4-70.1, 80.9-111.0 g/plant in mulched, NPK and mulched plus NPK, respectively, compared to the control. Therefore, the combined use of sawdust mulch and NPK fertilizer provided a better option in increasing fertilizer use efficiency and a more balanced nutrient supply in addition to providing all the benefits of mulching.

CONCLUSION

The results of this study revealed that although mulching with sawdust did not significantly influenced pepper growth; it did increase significantly the yield and yield components of pepper. Application of NPK 15:15:15 fertilizer above 300 kg ha^{-1} in sole or in combination with sawdust resulted in significant decrease in pepper yield. However, maximum pepper yield was obtained with combined use of sawdust mulch plus NPK fertilizer rate of 300 kg ha^{-1}.

SIGNIFICANCE STATEMENT

This study discovered that sawdust mulch supplemented with 300 kg ha^{-1} NPK fertilizer was beneficial for optimal production of pepper. This study will help Agriculturists, farmers and researchers to uncover the critical areas of utilization of sawdust waste for crop production that many researchers were not able to explore. Thus a new theory on waste utilization may be arrived at.

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