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Studies on the Influence of Rubber Effluent and NPK Application on the Performance and Fruit Quality of Snake Tomato (*Trichosanthes cucumerina L. Haines*) in Newly Established Rubber Plantation

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Abstract:
Rubber (latex) production suffered serious drawback in the mid-1970s to late 1990s due to the withdrawal of small holder rubber growers arisen from low pricing and other agronomic challenges. A field study was carried out in 2018 and 2019 cropping season to evaluate the influence of rubber effluent and NPK fertilizer on the performance and fruit quality of snake tomato in a newly established rubber plantation in Iyanomo. The treatments involved sole snake tomato, sole rubber and their intercropped combinations with NPK (applied at 60 kg N ha-1) and rubber effluent application rates (0, 50, 60 and 70 kg N ha-1) laid out in a randomized complete block design replicated three times. Data were collected on vine length, vine girth, number of leaves, leaf area, fruit yield components, nutrient content and uptake. Results showed that NPK and rubber effluent significantly ($P<0.05$) affected growth characters and fruit yield of snake tomato positively. The fertilized plants were higher in all the characters accessed than the unfertilized plants. Sole and intercropped snake tomato fruit yield with or without treatments had similar values. Unfertilized sole and intercropped snake tomato had the lowest fruit yield. The highest fruit yield was obtained from sole and intercropped snake tomato treated with NPK (STNPK and RSNPK). The number of rotten fruits were more in the unfertilized plants compared to the fertilized plants. Nutrient content and uptake were positively influenced by soil amendments.

Keywords: Growth, fruit yield components, intercrop, NPK and rubber effluent.

INTRODUCTION

Rubber (*Hevea brasiliensis* Wild ex A. de Juss. Muell.Arg.) is a plant commercially grown in plantations for the white exudates (latex) belonging to the family Euphorbiceae. The latex is processed into crumb and sheet rubber for export. The processed latex is a raw material for the production of Elastomers. Hence, this crop serves as a mean of foreign exchange and employment (Asokan *et al.* 2000).

Despite the relevant of Rubber in the economic development of Nigeria. The country suffered a serious set-back from mid-1970s to late 1990s owing to the withdrawal of the small holder rubber grower who are the grower of this crop as constituted about 25 % of the total latex production in Nigeria (NRAN, 2014). Their withdrawal was due to discouragement resulting from low prices of processed latex in the international market and other agronomic challenges (NRAN, 2013). The agronomic challenges include the long gestation period of rubber (5 to 7years), that deprived farmers of a sustainable income (income is tied down for 5-7 years without returns) during the immature phase and the fallow land brought about by rubber spacing (Michael, 2006). At present, the price of processed latex is high in the international market but latex production is still low. As a result, the nation cannot take advantage of its developmental drive. To be able to expand Natural rubber production in Nigeria, efforts must be put in to encourage and return the smallholder's rubber growers back to production. Hence, there is the need to developed appropriate plantation management systems that will assist farmers to reduce the gestation period of rubber, reduce cost of production and ensure early returns on investment. This can be achieved through the development of an agronomic system that will intercrop rubber with other arable crops preferably snake tomato.

Snake tomato is a neglected and under-utilized crops whose importance as an alternative to the regular tomato plant has increased in recent times as a result of the scarcity and untold price hike of the regular tomato during the off season and the recent invasion by *Tuta absoluta* that ravaged the entire tomatoes farm, has directed research efforts on snake tomato as an alternative to the regular tomato.

Cost of inorganic fertilizer, its availability, adulteration and its attendant effects on the world economy has been a source of concern, hence the need for an alternative. The disposal of rubber processing effluent has been a major challenge to factory owners and a source of pollution, but its use as soil nutrient amendment will go a long way to ameliorating the challenge and waste to wealth. Hence, this study was undertaken to evaluate the influence of rubber effluent and NPK fertilizer on the performance and fruit quality of snake tomato (*Trichosanthes cucumerina* L. Haines**)** in newly established rubber plantation

MATERIALS AND METHODS

Experimental Site

This study was conducted in 2018 and 2019 cropping seasons at the Research farm of Rubber Research Institute of Nigeria (RRIN), Iyanomo (lied within the ordinates of between latitude 6^{o}00 and 7^{o}00'N and longitude 5^{o}00' and 6^{o}00'E) near Benin City, Edo State, located within the Rain Forest zone of Nigeria. The rainfall pattern is bimodal with the peaks in the month of July and September but the highest in July and a short dry spell in August. The soils of this humid forest belt are mainly ultisols and the site is classified locally as kulfo series with pH range between 4.0 and 5.5.

Experimental design and field layout

The treatments involved a combination of sole rubber and snake tomato and intercropped combination with NPK (applied at 60 kg ha^{-1}) and rubber effluent application rates (0, 50, 60 and 70 kg ha^{-1}) laid out in a randomized complete block design in three replications. For snake tomato component in the intercrop, the treatments were:

- RE1RS-Rubber Effluent at application rate of 50 Kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)
- RE1ST- Rubber Effluent at application rate of 50 Kg N ha^{-1} cropped with sole snake tomato
- RE2RS- Rubber Effluent at application rate of 60 Kg N ha^{-1} cropped with rubber and Snake tomato (Intercrop)
- RE2ST- Rubber Effluent at application rate of 60 Kg N ha^{-1} cropped with sole snake tomato

- RE3RS- Rubber Effluent at application rate of 70 Kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)
- RE3ST- Rubber Effluent at application rate of 60 Kg N ha^{-1} cropped with sole snake tomato
- RSC- Rubber and Snake Tomato intercrop without fertilizer treatment
- RSNPK – Rubber –snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15
- STC- Sole Snake Tomato control
- STNPK – Sole snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

Prior to cropping with rubber and snake tomato, soil samples were randomly collected from the experimental site at a depth of 0 - 30 cm depth using auger and bulked together to form a composite sample. The composite soil sample was air-dried and sieved through a 2 mm mesh and analyzed for its physical and chemical properties using standard laboratory procedures. After harvest, soil samples were randomly collected from each plot separately and analyzed for its post-harvest chemical properties according to methods in Mylavarapus and Kennelley (2002). The oil had pH, organic C, total N, available P, exchangeable Ca, Mg, K, Na and acidity of 5.40, 17.20 g kg^{-1}, 0.84 g kg^{-1}, 10.50 mg kg^{-1}, 0.80 cmol kg^{-1}, 0.20 cmol kg^{-1}, 0.16 cmol kg^{-1}, 0.06 cmol kg^{-1} and 0.30 cmol kg^{-1}, respectively. The proximate nutrient composition of the rubber effluent was pH 6.20, organic C 29.60 %, total N 1.10 %, P 2.03 %, Mg 0.38 %, Ca 0.49%, chemical oxygen demand, biochemical oxygen demand and total dissolved solids were 410.00, 250.00 and 760.00 mg l^{-1}, respectively.

Cultural Practices

A field measuring 26 by 60 m was cleared of the existing vegetation manually with the aid of cutlasses and hoes, the debris were packed out of the site, thereafter the field was marked out into plots measuring 3 by 7 m with a metre pathway. The rubber effluent was applied immediately to the designated plots as per treatment. The Rubber saplings were transplanted to the field, two weeks after application of effluent. The pulled budded stump (young rubber) was placed in the hole in such a way that the budded patch is just above the ground level at a spacing of 3 by 7 m which gave rise to 476 rubber stands per hectare, each plot had four rubber stands. The snake tomato seedlings of two weeks old in a poly bag nursery filled with a mixture of top soil and poultry at a ratio of 3:1 was transplanted to the designated plots, a week after planting-out of rubber sapling at a spacing of 0.5 by 0.5 m which gave rise to a total of 40000 plants per hectare. The NPK was applied to the designated plots as per treatment two weeks after transplanting of snake tomato seedlings.

Trellis was erected on the plots cropped with snake tomato seedlings immediately and directed to climb through the twine. Weeding was carried out first at six weeks after transplanting and subsequently as at when due. In due time, fruits were harvested as they ripen.

Data Collection and Analysis

Three plants within the middle row of each plot were randomly selected for Data collection on the growth (vine length, vine girth, number of leaves per plant and leaf area) of snake tomato at 50 % flowering day. At harvesting of fruits of snake tomato, data were collected on fruit length, fruit diameter, number of fruits per plant, fruit weight, number of rotten fruits per plant and fruit yield. Three harvested fruits were randomly selected from each plot and oven dried separated at 60 ^{0}C for 72 hours to a constant weight. Each dry sample was ground and passed through 0.5 mm, sieve for nutrient content (N, P, K, Ca and Mg) content determination using IITA (1979) Method. The uptake was obtained through the product of nutrient content of the fruit and weight of its dry matter.

Analysis of variance was carried out on each of the data collected after estimating the mean for two years with GENSTAT programme and means were compared using least significant different (LSD) at 0.05 level of probability.

RESULTS

Growth

The effect of NPK and rubber effluent on growth and days to first and 50 % flowering of snake tomato in sole and intercropped with rubber grown on a newly established rubber plantation are presented in Table 1. The shortest vines were observed in the sole and intercrop snake tomato (RSC and STC) plots. Snake tomato plants raised in STNPK and RSNPK plots. All fertilized plots cropped with sole and intercropped snake tomato had longer vines than snake tomato plants on unfertilized plots. Increased in rubber effluent application rate brought about increase in vine length. However, vines were longer in plants grown in plots treated with NPK than rubber effluent at 70 kg N ha^{-1}. This distribution trend was mirrored for vine girth, number of leaves per plant and leaf area.

RSC plants had most days to first flowering but not significantly different (P>0.05) from STC, RE1RS and RE1ST plants. Sole and intercrop snake tomato grown on plots treated with NPK (STNPK and RSNPK) were earliest to first flowering, this distribution trend was reported for days to 50 % flowering. The growth values accrued to first cropping were higher than in the second cropping.

Fruit Yield and Components of Snake Tomato

The fruit yield indices of snake tomato in sole and intercrop with rubber as influenced by NPK and rubber effluent cropped in a newly established rubber plantation is presented in Table 2. Sole snake tomato and intercrop treated with NPK (STNPK and RSNPK) had the longest fruits. Sole snake tomato plants in STC had the shortest fruits but similar with fruits produced from RSC, RE1RS and RE1ST. The thinnest fruits were produced from RSC but similar with STC, RE1RS and RE1ST plants. The thickest fruits were recorded in STNPK plants but not significantly different from RSNPK, RE3ST and RE3RS.

The highest number of fruits per plant was recorded in RSNPK and STNPK. The fewest number of fruits was produced from STC plot which was identical with RSC plants. Heaviest fruits were produced by plants in STNPK. Fruits of snake tomato intercropped with rubber grown in unfertilized (RSC) plots were the lightest but not significantly different from RE1RS, RE2RS, RE3Rs and STC.

Number of rotten fruits per plant was comparable among all treatments. Snake tomato plant intercropped with rubber without fertilization (RSC) had the lowest fruit yield but comparable with the fruit yield in RE1RS, RE1ST and RSC plants. The highest fruit yield was recorded in RSNPK plants which was identical with the fruit yield recorded in STNPK plants. Higher fruit yield components were observed in the first year than in the second year.

Table 1: Effect of soil amendment on the growth of snake tomato at 50 % flowering day cropped in newly established rubber plantation

Treat ment	Vine length (cm)			Stem girth (cm)			Number of leaves			Leaf area (cm^2)			Days to 1st flowering					
	1st year	2nd year	Com bined	1st year	2nd year	Com bined	1st year	2nd year	Com bined	1st year	2nd year	Com bined	1st year	2nd year	Com bined	1st year	2nd year	Com bined
RE1RS	153	220.7	186.8	0.53	0.27	0.4	17	16	16.5	663.3	341	507.7	44.33	61	52.67	58.67	75.67	67.17
RE1ST	149.3	221.3	185.3	0.6	0.27	0.43	16	16	16	620.3	357	594.2	43.33	61.67	52.5	58	74	66
RE2RS	199.7	246	222.8	0.67	0.4	0.53	19.33	16.67	18	824.7	422	620.7	42	60.67	51.33	57.67	71	64.33
RE2S2	193.3	245.3	219.3	0.7	0.37	0.53	20.17	16.67	18.42	920.8	429	680.1	42	61.67	51.83	56.67	71.33	64
RE3RS	252.3	255.3	253.8	0.83	0.57	0.7	21.67	20.67	21.17	1090.7	635	842.7	42	60.33	51.17	55.67	68	61.83
RE3ST	243.7	254.7	249.2	0.87	0.57	0.72	21.67	20.67	21.17	1090	661	854.3	41.33	60.67	51	56.33	66.67	61.5
RSC	227.3	680	147.7	0.57	0.27	0.42	18.83	12.67	15.75	760	257	504	45.67	61.33	53.5	59.67	74.33	67
RSNPK	296	312	304	0.9	0.63	0.77	22	26	24	1496	1335	1389.3	40	51.67	45.83	45.67	62.67	54.17
STC	221.3	67	144.2	0.53	0.27	0.4	18.17	12.33	15.5	753.3	264	494	44.67	61	52.83	59.67	74.67	67.17
STNPK	289.7	310	299.8	0.97	0.67	0.82	22.67	25	23.83	1647.3	1302	1431	40.33	51	45.67	46	61.33	53.67
Mean	222.6	220	221.3	0.72	0.43	0.57	19.82	18.27	19.04	986.6	600	781.8	42.57	59.1	50.83	55.4	69.97	62.68
$LSD_{(0.05)}$	18.52	2.72	9.18	0.09	0.1	0.062	1.49	2.67	1.557	93.52	133.1	58.87	1.18	2.08	1.138	1.97	4.51	2.475
$LSD_{(0.05)}$ year	4.1			0.03			0.7			26.33			0.51			1.11		

Foot note

RE1RS - Rubber effluent at application rate of 50 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE1ST - Rubber effluent at application rate of 50 kg N ha^{-1} snake tomato (Sole)

RE2RS - Rubber effluent at application rate of 60 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE2ST - Rubber effluent at application rate of 60 kg N ha^{-1} snake tomato (Sole)

RE3RS - Rubber effluent at application rate of 70 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE3ST - Rubber effluent at application rate of 70 kg N ha^{-1} snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

RSNPK - Rubber-snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

Table 2: Effect of soil amendment on fruit yield and its components of snake tomato cropped in newly established rubber plantation

Treatment	Fruit length (cm)			Fruit diameter (cm)			Number of fruits per plant			Fruit weight (kg fruit^{-1})			Number of rotten fruits			Fruit yield (t ha^{-1})		
	1st	2nd year	`	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined
RE1RS	47.00	39.00	43.00	4.77	3.90	4.33	9.00	8.67	8.83	0.80	0.70	0.75	3.00	3.33	3.17	28.60	23.10	25.90
RE1ST	48.00	38.33	43.17	4.60	3.63	4.12	8.00	10.00	9.00	0.93	0.73	0.83	2.67	3.67	3.17	28.30	27.90	28.10
RE2RS	55.00	42.33	48.67	5.70	4.70	5.20	16.00	12.67	14.33	0.87	0.77	0.82	2.33	3.33	2.83	52.20	36.70	44.50
RE2S2	56.33	41.33	48.83	5.70	4.73	5.22	15.67	13.67	14.67	0.83	0.73	0.78	2.33	4.00	3.17	50.20	37.90	44.00
RE3RS	57.67	43.67	50.67	5.70	4.87	5.28	20.33	14.00	17.17	1.20	0.77	0.98	1.33	4.00	2.67	86.40	40.80	63.60
RE3ST	57.17	43.33	50.25	6.20	5.20	5.70	20.33	14.33	17.33	0.93	0.83	0.88	1.00	4.67	2.83	71.40	45.50	58.40
RSC	44.40	38.00	41.20	5.03	3.23	4.13	7.00	8.33	7.67	0.63	0.67	0.65	3.67	3.00	3.33	17.00	21.10	19.10
RSNPK	60.33	56.67	58.50	6.23	5.17	5.70	25.33	19.33	22.33	1.40	0.90	1.15	1.00	4.67	2.83	135.20	66.10	100.70
STC	43.33	37.33	40.33	5.40	3.17	4.28	6.67	7.07	7.17	1.07	0.70	0.88	3.67	3.00	3.33	27.50	20.30	23.90
STNPK	61.33	57.33	59.33	6.47	5.17	5.82	26.67	18.00	22.33	1.67	0.93	1.30	1.00	4.33	2.67	169.20	63.60	116.40
Mean	53.06	43.73	48.39	5.58	4.37	4.98	15.50	12.67	14.08	1.03	0.77	0.90	2..20	3.80	3.00	66.60	38.30	52.40
$LSD_{(0.05)}$	4.170	3.73	2.654	0.48	0.88	0.573	1.77	2.92	1.719	0.24	0.12	0.133	1.01	1.34	ns	20.230	9.820	10.550
$LSD_{(0.05)}$ year		1.190			0.26			0.77			0.06			0.36			4.720	

Foot note

RE1RS - Rubber effluent at application rate of 50 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE1ST - Rubber effluent at application rate of 50 kg N ha^{-1} snake tomato (Sole)

RE2RS - Rubber effluent at application rate of 60 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE2ST - Rubber effluent at application rate of 60 kg N ha^{-1} snake tomato (Sole)

RE3RS - Rubber effluent at application rate of 70 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE3ST - Rubber effluent at application rate of 70 kg N ha^{-1} snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

RSNPK - Rubber-snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

Nutrient Content of Snake Tomato

The nutrient content of snake tomato in sole and intercrop with rubber cropped in a newly established rubber plantation is presented in Table 3. N content ranged from 0.05 % for STC, RSC and RE1ST plants and 0.25 % for RE3RS plants. However, N content RSC, STC and RE1ST plants were at par with RE2ST. The lowest P content was observed in RE1RS plants which was similar with P content observed in STC, RSC and RE1ST plants while STNPK plants had the highest P content which were comparable with RE3RS, RE3ST and RSNPK plants. STNPK and RSC plants had the highest and lowest K concentration, respectively. STNPK plants had the highest Ca concentration while the lowest was observed in RSC and STC plants. The lowest and highest Mg were observed in RSC and RE1RS plants, respectively.

Nutrient Uptake of Snake Tomato

Results of the effect of NPK and rubber effluent on the nutrient uptake of snake tomato in sole and intercrop with rubber grown on a newly established rubber plantation is presented in Table 4. RSC plants had the lowest N uptake while the highest was observed in STNPK plants. However, P uptake was similar among treatments. The lowest K uptake was recorded in STC plants while the highest K uptake was observed in STNPK plants. Calcium (Ca) uptake was lowest and highest in STC and STNPK plants, respectively. The lowest Mg uptake was observed in STC plants but similar with Mg uptake obtained from RSC, RE3RS and RE1RS. The highest Mg content was recorded in RE3ST plants but at par with Mg uptake obtained with STNPK, RSNPK, RE2ST, RE2RS and RE1ST.

DISCUSSION

The study has showed that during the first two years of rubber cultivation, snake tomato can be cropped successfully between rubber plants spaces thereby contributing positively to national food security and ensuring land sustainability. The performance of snake tomato was not adversely affected by its intercropped with rubber as the growth and yield of the sole and intercropped snake tomato were similar. This evidenced from the fact that vine length, vine girth, number of leaves, leaf area and fruit yield exhibited similar values between intercrop and sole snake tomato.

Table 3: Effect of soil amendment on nutrient content of snake tomato fruit cropped in newly established rubber plantation

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Calcium (%)			Magnesium (%)		
	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined
RE1RS	0.03	0.16	0.10	0.10	0.14	0.12	1.43	2.05	1.73	0.81	0.95	0.88	1.07	1.54	1.30
RE1ST	0.04	0.06	0.05	0.14	0.08	0.11	1.43	1.20	1.32	0.37	0.75	0.56	1.24	0.84	1.04
RE2RS	0.04	0.06	0.05	0.10	0.14	0.12	1.15	1.28	1.21	0.79	0.89	0.84	0.34	1.37	0.86
RE2ST	0.08	0.03	0.06	0.14	0.15	0.15	1.17	1.82	1.50	0.87	0.65	0.76	0.45	0.39	0.42
RE3RS	0.34	0.15	0.25	0.14	0.15	0.15	1.14	0.32	0.73	0.80	0.76	0.78	0.29	1.31	0.80
RE3ST	0.08	0.06	0.07	0.10	0.10	0.10	1.30	0.95	1.13	0.75	0.70	0.73	1.32	0.87	1.10
RSC	0.04	0.15	0.05	0.15	0.11	0.80	1.34	1.41	1.38	1.20	0.75	0.98	0.75	0.68	0.72
RSNPK	0.07	0.15	0.11	0.10	0.15	0.13	1.24	1.18	1.21	0.85	0.81	0.83	1.26	1.26	1.26
STC	0.06	0.08	0.07	0.14	0.15	0.14	1.27	1.59	1.43	0.18	0.85	0.52	1.37	1.06	1.22
STNPK	0.15	0.08	0.12	0.15	0.10	0.13	0.32	1.19	0.76	1.49	0.46	0.98	1.31	0.78	1.05
Mean	0.090	0.09	0.09	0.13	0.13	0.19	1.43	1.30	1.24	0.81	0.76	0.78	0.93	1.00	0.97
$LSD_{(0.05)}$	0.110	0.017	0.011	ns	0.015	0.028	0.006	0.017	0.011	0.006	0.055	0.029	0.006	0.017	0.11
$LSD_{(0.05)}$ year	ns			0.012			0.005			0.013			0.005		

Foot note

RE1RS - Rubber effluent at application rate of 50 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE1ST - Rubber effluent at application rate of 50 kg N ha^{-1} snake tomato (Sole)

RE2RS - Rubber effluent at application rate of 60 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE2ST - Rubber effluent at application rate of 60 kg N ha^{-1} snake tomato (Sole)

RE3RS - Rubber effluent at application rate of 70 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE3ST - Rubber effluent at application rate of 70 kg N ha^{-1} snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

RSNPK - Rubber-snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

In the first year cropping in the newly established rubber plantation, the fruit yield of snake tomato plants were higher in STNPK than plants in RSNPK but in the other year their yields were comparable. This observation is in line with Esekhade *et al*. (1996) who reported that both food and horticultural crops can be intercropped with rubber during the immature period as they had no adverse effect on rubber. The competition for space, light, water and nutrients was not intense in the young rubber plantation since rubber plant requirement at this stage is minimal but will gradually increase as the plant aged. This may have accounted for the gradual reduction in growth and economic yield of snake tomato as the rubber plant aged.

Table 4: Effect of soil amendment on nutrient content of snake tomato fruit cropped in newly established rubber plantation

Treatment	Nitrogen (g kg^{-1})			Phosphorus (g kg^{-1})			Potassium (g kg^{-1})			Calcium (g kg^{-1})			Magnesium (g kg^{-1})		
	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined	1st	2nd year	Combined
RE1RS	5.43	2.96	4.19	16.40	62.16	39.30	2.96	5.43	4.20	62.16	16.40	39.30	41.44	6.65	24.00
RE1ST	4.07	2.03	3.05	11.70	54.08	32.90	2.03	4.07	3.05	54.08	11.70	32.90	88.25	40.67	64.50
RE2RS	4.03	4.40	4.21	6.20	46.20	26.20	4.40	4.03	4.22	46.21	6.20	26.20	59.04	60.74	59.90
RE2S2	4.62	2.52	3.57	11.10	73.50	42.30	2.52	4.62	3.57	73.50	11.10	42.30	58.80	67.24	63.00
RE3RS	3.67	1.00	2.33	8.70	32.66	20.70	1.00	3.67	2.33	32.66	8.70	20.70	40.67	45.92	43.30
RE3ST	4.55	2.27	3.41	9.30	54.35	31.80	2.27	4.53	3.41	54.34	9.30	31.80	54.67	94.04	74.20
RSC	4.38	2.84	3.61	2.70	70.31	36.20	2.84	4.38	3.61	70.31	2.70	36.20	54.34	10.36	38.80
RSNPK	5.68	4.13	4.90	1.50	65.10	33.30	4.13	5.68	4.91	65.10	1.50	33.30	67.24	34.58	64.30
STC	5.03	4.28	4.65	1.50	13.80	7.60	4.28	5.04	4.66	13.00	1.50	7.60	94.04	1.44	33.00
STNPK	4.96	2.47	3.71	9.50	88.20	48.90	2.47	4.96	3.72	88.20	9.50	48.90	24.66	59.04	62.60
Mean	4.64	2.89	3.77	7.80	56.04	31.90	2.89	4.64	3.77	56.04	7.80	31.90	66.15	46.07	52.80
$LSD_{(0.05)}$	0.200	0.049	0.021	0.012	0.110	ns	0.120	0.006	0.029	0.009	0.640	0.013	0.006	0.500	22.72
$LSD_{(0.05)}$ year	0.013			0.005			0.130			0.006			0.005		

Foot note

RE1RS - Rubber effluent at application rate of 50 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE1ST - Rubber effluent at application rate of 50 kg N ha^{-1} snake tomato (Sole)

RE2RS - Rubber effluent at application rate of 60 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE2ST - Rubber effluent at application rate of 60 kg N ha^{-1} snake tomato (Sole)

RE3RS - Rubber effluent at application rate of 70 kg N ha^{-1} cropped with rubber and snake tomato (Intercrop)

RE3ST - Rubber effluent at application rate of 70 kg N ha^{-1} snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

RSNPK - Rubber-snake tomato treated with 60 kg N ha^{-1} of NPK 15:15:15

The soils of the experimental site were strongly acidic with values lower than critical level for the availability of some essential nutrients. This implied that the soil had low fertility status. Law-Ogbomo and Osaigbovo (2018) reported that most Nigerian soils are of low in native fertility owing to the highly weathered soils coupled with leaching and continuous cropping. Soil fertility is a very important factor in soil productivity in relation to nutrient and yield (Erhabor, 2005).

Plants need supply of appropriate proportionate essential nutrients from the soil for optimum growth, development and yield. Low soil fertility status without adequate soil nutrient supplementation will result in growth and yield depression due to nutrient deficiencies (Law-Ogbomo *et al*., 2020). From the the analysis of the rubber effluent, it was found to be moderately acidic and contained N, P, K and Ca in appreciable quantity. The effluent has high concentration of organic carbon, combined oxygen demand and biochemical oxygen demand at safe level. This finding is in agreement with Orhue *et al*. (2007) who reported highly significant amount of total suspended and dissolved solids, phosphate and total N in rubber effluent. Orhue and Osaigbovo, (2013) reported that rubber effluent had great potential as organic fertilizer and could be beneficial to arable crops without additional cost as effluent are waste product of rubber processing factories and its disposal has been a major concern to rubber processing factory owners. This is an indication that rubber effluent which ought to be waste and pollutant to the environment can be made to be an avenue for wealth creation through its conversion to organic fertilizer.

Days to first and fifty percent flowering were earlier in NPK and rubber effluent at higher application level treated plants. However, NPK treated plants were earliness to first and fifty percent flowering than rubber effluent and untreated plants. The fertilized plants were earlier to flowering probably due to the enhancement of their vegetative phase through the stimulating effect of the readily available nutrients on photosynthetic processes leading to early flower initiation. The early flowering was advantageous to plants fertilized with NPK and rubber effluent applied at higher rate as it resulted in higher yield.

The high snake tomato yield with longer, heavier and higher number of fruits per plants accrued to plants treated with soil amendment is clear evidence that rubber effluent and NPK enhanced yield positively. This observation is in agreement with Mbonu and Arifalo (2016) who reported that, the use of readily available fertilizer enhances the yield of the plant. In this present study, yield was most enhanced with NPK. Snake tomato plant treated with rubber effluent applied at 50 Kg N ha^{-1} had similar yield with plants without fertilizer treatment. This implies that rubber effluent application only enhanced fruit yield at higher application rate.

The reduction in fruit yield of snake tomato observed in plants grown on unfertilized plots could have arisen from insufficient nutrient uptake as the plant have to rely on nutrients from the soil which have been found to be less than the critical level in some essential plant nutrients. Apart from the nutrient being low, there could be a problem of availability of phosphorus, calcium and magnesium to the plant since pH was less than 5.50 indicating strong acidity. Plants grown on plots without fertilizer application had shorter and thinner vines with lower number of leaves and leaf area leading to reduction in fruit yield and components. Lower field yield could be due to inadequate production of assimilates owing to low nutrients availability to plants. This is an indication that growth and yield of snake tomato depends on residual soil nutrients.

The higher yield obtained from plants treated with NPK and higher rate of rubber effluent is a reflection of the application of fertilizer to the soil through improved supply of nutrients to plants leading to better utilization of carbon and consequent synthesis of assimilates. Adequate nutrient availability has been indicated to be useful to the growth and yield of snake tomato. This clearly demonstrated the benefit of the application of soil amendments. The application of soil amendment boosted the enhancement of vine length, vine girth, number of leaves and leaf area leading to the production of abundant assimilates which resulted in higher fruit yield.

The study demonstrated that intercropping rubber plant with snake tomato had no adverse effect on nutrient content and uptake of snake tomato. This was evidenced from the comparable values obtained between the sole and intercrop snake tomato. However, in the unfertilized plots, the intercrop snake tomato plants were relatively poor in nutrient content and uptake compared to the fertilized plots. This implies that in nutrient stress situation, competition for available nutrients will intensify giving rise to poorer quality of intercrop snake tomato yield.

CONCLUSION AND RECOMMENDATION

Based on the findings from this study, snake the study shows that intercropping rubber plant with snake tomato was desirable as the inter-plant competition was not intense. It ensures that farmers start reaping fruits from the enterprise from the first year. Fertilizer application increased the growth and fruit yield of snake tomato. Nutrient content and uptake by snake tomato were enhanced through fertilizer application. There were growth and yield disparity between NPK and rubber effluent treated plants, however, the application of rubber effluent at 70 kg N ha^{-1} showed promising. NPK should be applied at 60 Kg N ha^{-1} (400 Kg NPK ha^{-1}) to increase fruit yield performance and fruit quality of snake tomato.

tomato intercropping with rubber should be supplemented with fertilizer application to improve the fertility of the soil to sustain soil and higher growth of rubber and yield of snake tomato.

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Effect of Different Potassium Rates on the Growth and Productivity of Onion

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Abstract:
The experiment was conducted during the year 2021 at the Horticultural Orchard, Sindh Agriculture University, TandoJam, to investigate the effect of potassium different rates on growth and productivity of onion, in a three replicated randomized complete block design using plot size 3m x 3.5m (10.5m^2). The potassium rate includes T1=Control, T_2 = 20 kg (K) ha-1, T3= 40 kg (K) ha-1, T4 = 60 kg ha-1, T5 = 80 kg (K) ha-1 and T6 = 100 kg (K) ha-1. The present study results were statistically significant for growth and yield of onion. The potassium rates T6 = 100 kg (K) ha-1 produced highest growth and yield for all parameters including plant height (52.33 cm), stem girth (55.60 cm), number of leaves plant-1 (13.00), weight of leaves plant (66.90 g), bulb diameter (6.40 cm), single bulb weight (106.67 g), yield plot-1 (6.4 kg) and yield ha-1 (6095.2 kg) was recorded in T6 = 100 kg (K) ha-1. The average data was Plant height (48.83 cm), stem girth (53.32 cm), number of leaves plant-1 (10.00), weight of leaves plant-1 (63.90 g), bulb diameter (5.73 cm), single bulb weight (93.00 g), yield plot-1 (5.58 kg) and yield ha ha-1 (5314.3 kg) recorded in T5 = 80 kg (K) ha-1. Whereas the minimum data was Plant height (41.70 cm), stem girth (46.8 cm), number of leaves plant-1 (6.33), weight of leaves plant-1 (46.56 g), bulb diameter (3.33 cm), single bulb weight (49.33 g), yield plot-1 (2.96 kg) and yield ha-1 (2819.2 kg) recorded in T_1 = Control. It was concluded that T6 = 100 kg (K) ha-1 produced better results for all growth and yield parameters as compared to other potassium rates.

Keywords: Potassium, onion growth and productivity

INTRODUCTION

Onion (Allium cepa L), the most widely cultivated species of Amaryllidaceae, is important to many genus in the world. About 170 countries grow onions for domestic use or trade. In 2016, the global area was planted with an area of about 5 million hectares, which produced 93 million MT, with an average yield of 18 MT. Onion has diploid chromosome numbers 2n = 16. Onion is the most widely distributed herb plant in over 600 varieties worldwide. The onion has a low root system, long, linear and hollow pin, as it grows on the base structure (Ozkan et al., 2018).

Depending on the purpose and variety, onions can be made from seeds or bulbs. Onions are best planted in fertile soil, which is well dried. Without soil type, the maximum pH range is 6.0 to 6.8, although alkaline soils are also suitable. Onions are not dispersed in the ground below 6.0 because of the lack of trace element, or sometimes, because of the aluminum or manganese precipitate. Salt salts are better because they have less sulfur, while clay soils generally have higher sulfur content and produce a thicker bulb. Onions need significant levels of fertilizer in the soil (Aftab et al., 2017). In Pakistan, there is no doubt that Sindh province alone produces 666.8 thousand tonnes, which seems to double as compared to 303.2 thousand tonnes produced by the province of Punjab, especially due to the climatic conditions required by this crop (FBS, 2015). Both organic and inorganic fertilizer enhancing have an important response. Larger doses are commonly recommended for onion cultivation (Nasreen and Hussein, 2007). In high nutrients, potassium plays an important role in plant metabolism such, regulation of plant photosynthetic substrates, activation of plant regeneration and resistance to insects and diseases. It is also considered a quality factor because it improves the quality of many crops, including onions. Improves potassium as well as collects color, gloss and dries substances, it also maintains the onion bulb quality (Aftab et al., 2017). The application of potassium also improves the life of onion cultivars and some potassium also plays an important role in the production and quality as well as onion life. Potassium is involved in many metabolic processes such as carbohydrate and sugar production and transport, protein synthesis, enhances stomach and disease resistance and activates several enzymes. (Pachauri et al., 2005).

Potassium (K) helps in increasing the production of basal matter, being absorbed in large quantities, just beyond potassium (K). The beneficial effects of potassium can be found in a variety of agricultural products, such as color, acidity. Shipping resistance, handling and storage, nutritional value and industrial qualities (Kumar et al., 2001). Regarding working knowledge with K Pusa Madhvi, applying 40 kg/ha^{-1} of K2O reported an increase in onion yield and a decrease in diameter of the reaction at levels of 80 and 160 kg/ha^{-1} And the latest case of the bulb, using K2O at 60kg/ha^{-1}, nasik Red Cultivar, as well as an increase in diameter and fresh matter of the bulb, with the application of 60 kg/ha^{-1} of K2O. When studying five cultivars (k Lacara, Burgoyne, White Kriel, Swat and Texas Early Grano), it was found that onion bulb production increased by 200 kg ha^{-1} K2O, and the lowest yield of all crops showed a decrease in curry. General Chat Chat Lounge Fertility. Considering the importance of potassium (K), the present experiment was conducted to evaluate the effect of different rates of potassium-on-potassium growth and production (Akhtar et al. 2002).

MATERIALS AND METHODS

The experiment was conducted during the year 2020 at the Horticultural Orchard, Sindh Agriculture University. Tando Jam, to evaluate the effect of different potassium rates on the growth and productivity of onion. The experiment was conducted in Randomized complete block Design (RCBD). The study comprised of six different Potassium rates including T_1= Control where no potassium application was applied, T_2= 20 kg (K) ha^{-1} (40 g SOP plot^{-1}), T_3= 40 kg (K) ha^{-1} (80 g SOP plot^{-1}), T_4= 60 kg (K) ha^{-1} (120 g SOP plot^{-1}), T_5= 80 kg (K) ha^{-1} (160 g SOP plot^{-1}), T_6= 100 kg (K) ha^{-1} (200 g SOP plot^{-1}), each treatment was replicated three times.Uing plot size 3m x 3.5m (10.5m^2). A good seed bed was achieved by recommended practices for land preparation. The growth and yield response of onion was assessed by different potassium (K) application rates. The K was applied in the form of sulphate of potash (SOP).

Observation Recorded

1. Plant height (cm)
2. Stem girth (cm)
3. Number of leaves plant^{-1}
4. Weight of leaves plant $^{-1}$(g)
5. Bulb diameter (cm)

6. Single bulb weight (g)
7. Yield plot^{-1} (kg)
8. Yield ha^{-1} (kg)

Statistical Analysis
Data was statistically analysis to determine superiority of the treatment using ANOVA and least significant difference (LSD) tests. All statistical tests were performed using the computer software Statistic (Ver.8.1).

Procedure for Recoding Observation
Plant Height (cm):
Plant height was measured from the ground level up to the tip of the highest leaf using a standard ruler.

Number of Leaves Plant^{-1}:
Numbers of leaves plant-1 was calculated from randomly selected plants from each treatment.

Bulb Weight (g):
Weight of each bulb were collected and tagged at random and weighted to record the weight in (g).

Bulb Diameter (cm):
The diameter of all the bulbs in randomly selected plants was measured in centimeters with vernier caliper and average was worked out with the following

$$\text{Formula} = \text{Area} = 3.14 \times r^2$$

Average Yield Treatment^{-1}(kg):
Average yield was calculated as per plant weight of onion bulb taken from five plants per treatment then average was done

RESULTS

The experiment was conducted during the year 2020 at the Horticultural Orchard, Sindh Agriculture University, Tando Jam, in a three replicated randomized complete block design using plot size 3m x 3.5m (10.5m2). Observation was recorded for including plant height (cm), stem girth (cm), number of leaves plant^{-1}, weight of leaves plant^{-1} (g), bulb diameter (cm), single bulb weight (g), yield plot^{-1} (g), and yield ha^{-1}(kg)

Plant Height (cm)
The results in regard to plant height (cm) of onion under treatments of different Potassium (K) application rates are presented in table -1 The analysis variance suggested that plant height was significantly ($P<0.05$) affected by different potassium application rates.

The plant height of onion was significantly maximum (52.33 cm) when the plant was treated with T_6 =100 kg (K) ha, followed by plant height of 48.83 cm in plants treated with T_5 = 80 kg (K) ha". The onion plant height reduced considerably to 47.43, 46.73 and 45.13 cm, when plant was treated with T_4 = 60 kg (K) ha", T_3 = 40 kg (K) ha and T_2 = 20 kg (K) ha", respectively. However, the onion plant height was minimum (41.70 cm) under T_1 = Control where no potassium application was applied. The LSD test demonstrated that the differences in plant height (cm) treated by potassium application rates were significant ($P<0.05$).

Stem Girth (cm)

The results in regard to stem girth (cm) of onion under treatments of different Potassium K) application rates are presented in Table-1 The analysis variance suggested that stem girth was significantly ($P < 0.05$) affected by different potassium application rates The stem girth of onion was significantly maximum 55.60 (cm) when the plant was treated with T_6 = 100 kg (K) ha^{-1} followed by stem girth of 53.32 cm in plants treated with T_5 = 80kg (K) ha^{-1} The onion stem girth reduced considerably to 51.67, 51.33 and 49.33 cm, when plant was treated with T_4 = 60 kg (K) ha^{-1} T_3 = 40 kg (K) ha^{-1} and T_2 = 20 kg (K) ha^{-1} respectively However the onion stem girth was minimum (46.8 cm) under T_1=Control where no potassium application was applied The LSD test demonstrated that the differences in stem girth (cm) treated by potassium application rates were significant ($P < 0.05$).

Number of Leaves Plant^{-1}

The results in regard to number of leaves plant of onion under treatments of different Potassium (K) application rates are presented in Table1. The number of leaves plant of onion was significantly maximum (13.00) under T_6= 100 kg (K) ha^{-1} followed by number of leaves plant of 10.00 in plants treated with T_5=80 kg (K) ha^{-1} and T_4 = 60 kg (K) ha^{-1} weight reduced considerably to 9.00 and 8.00 when plant was treated with T_3 = 40 kg (K) ha^{-1} and T_2 = 20 kg (K) ha^{-1} respectively However, the onion number of leaves plant was minimum (6.33) under T_1 = Control where no potassium application was applied The LSD test demonstrated that the differences in number of leaves plant treated by potassium application rates were significant ($P<0.05$)

Table 1. plant height (cm), stem girth (cm) and number of leaves plant^{-1} of onion treated by potassium different rates.

Treatments	Plant height (cm)	Stem girth (cm)	Number of leaves plant^{-1}
T_1 = Control	40.70 e	46.8 f	6.33 e
T_2 = 20kg (k) ha^{-1}	45.13 d	49.33 e	8.00 d
T_3 = 40 kg (k) ha^{-1}	46.73 c	50.5 d	8.66 c
T_4 = 60 kg (k) ha^{-1}	47.43 c	51.67 c	10.00 b
T_5 = 80 kg (k) ha^{-1}	48.83 b	53.32 b	10.33 b
T_6 = 100 kg (k) ha^{-1}	52.33 a	55.60 a	12.88 a
F - Value	107	406	247
P - Value	0.0000	0.0000	0.0000
LSD 0.05	1.0641	0.4712	0.4416
CV%	1.27	0.52	2.64
S.E $\pm$	0.4884	0.2162	0.2027

Weight of Leaves Plant (g)

The results in regard to weight of leaves plant^{-1} (g) of onion under treatments of different Potassium (K) application rates are showed in figure -1. The weight of leaves plant^{-1} of onion was significantly maximum (66.90 g) when the plant was treated with T_6 = 100 kg (K) ha^{-1} followed by weight of leaves plant^{-1} of 63.90 g in plants treated with T_5 = 80 kg (K) ha^{-1}. The onion weight of leaves plant^{-1} reduced considerably to 59.51, 53.32 and 51.34 g, when plant was treated with T_4= 60 kg (K) ha, T_3= 40 kg (K) ha^{-1} and T_2= 20 kg (K) ha^{-1}, respectively. However, the onion weight of leaves plant^{-1} was minimum (46.56 g) under T_1= Control where no potassium application was applied. The LSD test demonstrated that the differences in weight of leaves plant (g) treated by potassium application rates were significant (P<0.05).

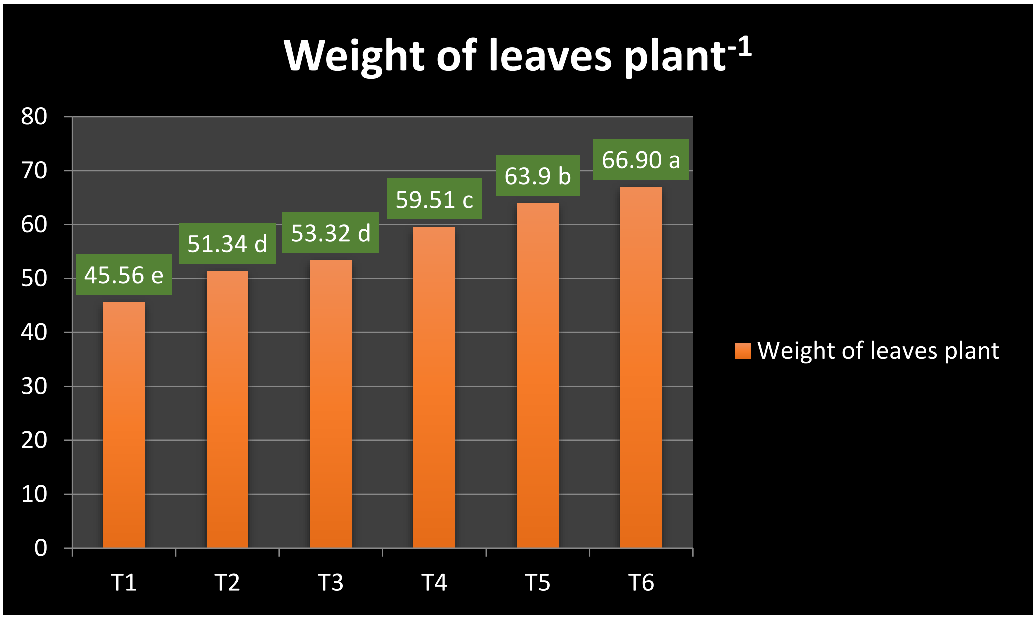

Figure 1. Weight of leaves plant^{-1} of onion treated by potassium different rates

Bulb Diameter (cm)

The results in regard to bulb diameter (cm) of onion under treatments of different Potassium (K) application rates are showed in Figure 2. The bulb diameter of onion was significantly maximum (6.40 cm) when the plant was treated with T_6 = 100 kg (K) ha^{-1} followed by bulb diameter of 5.73 cm in plants treated with T_5 = 80 kg (K) ha^{-1}. The onion bulb diameter reduced considerably to 5.33, 4.56 and 4.20 cm when plant was treated with T_4= 60 kg (K) ha^{-1}, 3 = 40kg (K) ha^{-1} T_2 = 20 kg (K) ha^{-1}, respectively However, the onion bulb diameter was minimum (3.33 cm) under T_1= Control where no potassium application was applied The LSD test demonstrated that the differences in bulb diameter (cm) treated by potassium application rates were significant (P < 0.05).

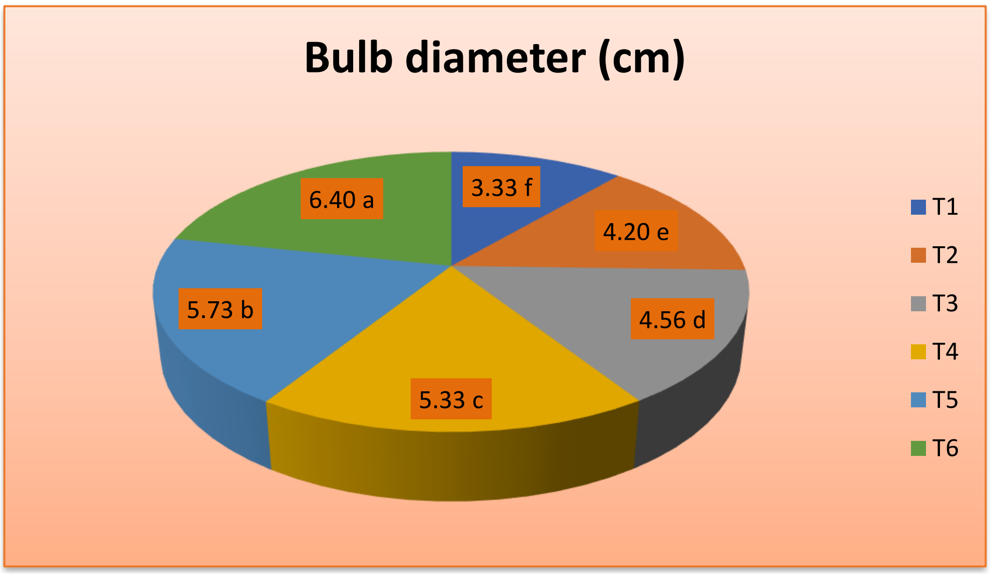

Figure 2. Bulb diameter (cm) of onion treated by potassium different rates

Single Bulb Weight (g)

The results in regard to single bulb weight (g) of onion under treatments of different Potassium (K) application rates are presented in Table -2. The single bulb weight of onion was significantly maximum (106.67 g) when the plant was treated with T_6 =100 kg (K) ha^{-1}, followed by single bulb weight of 93.00 g in plants treated with T_5 =80 kg (K) ha^{-1}. The onion single bulb weight reduced considerably to 83.00, 72.33 and 57.67 g, when plant was treated with T_4 = 60 kg (K) ha^{-1} T_3 = 40 kg (K) ha^{-1} and T_2 = 20 kg (K) ha^{-1}, respectively. However, the onion single bulb weight was minimum (49.33 g) under T_1 = Control where no potassium application was applied. The LSD test demonstrated that the differences in single bulb weight (g) treated by potassium application rates were significant ($P<0.05$).

Yield $Plot^{-1}$ (kg)

The results in regard to yield plot-1 (kg) of onion under treatments of different Potassium (K) application rates are presented in Table-2. The yield plot of onion was significantly maximum (6.4 kg) when the plant was treated with T_6 = 100 kg (K) ha^{-1}, followed by yield $plot^{-1}$ of 5.58 kg in plants treated with T_5 = 80 kg (K) ha^{-1}. The onion yield $plot^{-1}$ reduced considerably to 4.98, 4.34 and 3.46 kg, when plant was treated with T_4 = 60 kg (K) ha^{-1}, T_3 = 40 kg (K) ha^{-1} and T_2 = 20 kg (K) ha^{-1}, respectively. However, the onion yield $plot^{-1}$ was minimum (2.96 kg) under T_1 =Control where no potassium application was applied. The LSD test demonstrated that the differences in yield plot (kg) treated by potassium application rates were significant ($P<0.05$).

Yield Ha^{-1} (kg)

The results in regard to yield ha^{-1} (kg) of onion under treatments of different Potassium (K) application rates are presented in Table -2. The yield ha of onion was significantly maximum (6095.2 kg) when the plant was treated with T_6 = 100 kg (K) ha^{-1}, followed by yield ha^{-1} of 5314.3 kg in plants treated with T_5 = 80 kg (K) ha^{-1}. The onion yield ha^{-1} reduced considerably to 4721.2, 4133.3 and 3295.2 kg, when plant was treated with T_4 = 60 kg (K) ha^{-1}, T_3 = 40 kg (K) ha^{-1} and T_2 = 20 kg (K) ha^{-1}, respectively. However, the onion yield ha^{-1} was minimum (2819.2 kg) under T_1 = Control where no potassium application was applied. The LSD test demonstrated that the differences in yield ha" (kg) treated by potassium application rates were significant ($P<0.05$).

Table 2. Single bulb weight (g), yield $plot^{-1}$ (kg) and yield ha^{-1} (kg) of onion treated by potassium different rates.

Treatments	Single bulb weight (g)	Yield $plot^{-1}$ (kg)	Yield ha^{-1} (kg)
T_1 = Control	49.33 f	2.96 f	2819.2 f
T_2 = 20kg (k) ha^{-1}	57.67 e	3.46 e	3295.2 e
T_3 = 40 kg (k) ha^{-1}	72.33 d	4.34 d	4133.3 d
T_4 = 60 kg (k) ha^{-1}	83.00 c	4.98 c	4721.2 c
T_5 = 80 kg (k) ha^{-1}	93.00 b	5.58 b	5314.3 b
T_6 = 100 kg (k) ha^{-1}	103.33 a	6.4 a	6095.2 a
F - Value	174	174	168
P-Value	0.0000	0.0000	0.0000
LSD 0.05	5.0492	302.95	293.22
CV%	3.69	3.69	3.75
S.E $\pm$	2.3174	139.04	134.58

DISCUSSION

Among the major nutrients, potassium plays a vital role in plant metabolism such as photosynthesis, translocation of photosynthetic substrates regulation of plant pores, activation of plant catalysts and resistance against pests and diseases. It is also considered as a quality element as it improves quality parameters of many crops including onion. Potassium improves color, glossiness and dry matter accumulation besides improving, it also keeping bulb quality of onion (Aftab et al. 2017). Potassium application also improved the post-harvest life of onion and some other Potassium also plays important role in production and quality as well as shelf- life of onion. Potassium is helpful in many metabolic processes namely, production and transport of carbohydrates and sugars, protein synthesis, imparting resistance to pests and diseases and activation of many enzymes (Pachauri et al., 2005). Potassium (K) contributes markedly to improving the production of onion, being absorbed in large amounts, exceeded only by potassium (K). The beneficial effect of potassium can be found in different traits of agricultural products, such as color, acidity, resistance to shipping, handling and storage, nutritional value and industrial qualities (Kumar et al., 2001).

The present study results finding statistically significant for different potassium different rates. The data was recorded for plant height (cm), stem girth (cm), number of leaves plant^{-1}, weight of leaves plant (g), bulb diameter (cm), single bulb weight (g), yield plot^{-1} (kg) and yield ha^{-1} (kg). Among the different potassium rates T -100 kg (K) ha^{-1} had better results for all parameters. The present study finding results were resemble with (Aftab et al., 2017). They reported that potassium application of 120 kg/ha^{-1} is recommended as the most suitable dose for obtaining maximum yield of onion.

The present study findings that the plant height (cm) was statistically significant treated with potassium rates. The highest plant height was observed where T_6 = 100 kg (K) ha^{-1} was applied. Awatef et al. (2015) studied the potassium levels 100 kg (K) ha produced highest plant height.

Furthermore, present study results the bulb weight and bulb diameter were also recorded highest under T_6 = 100 kg (K) ha^{-1}. Aftab et al. (2017) indicated that maximum average bulb weight (78.44 g) and maximum bulb diameter (5.20 cm) maximum was noted in plots applied with potassium at the rate of 120 kg/ha^{-1}, Islam et al. (2008) also reported that potassium had significant effect on bulb diameter and bulb weight and also size.

The bulb yield parameters had also significant results treated with potassium T_6 = 100 kg (K) ha^{-1}. The present study results similar with (Siddiquee et al. (2008). They observed that It was observed that the application of K @ 100 kg ha^{-1} significantly increased the yield of onion. Aftab et al. (2017) reported that potassium application of 120 kg/ha^{-1} is recommended as the most suitable dose for obtaining maximum yield of onion. Furthermore, scientists reported that split application of 120 kg/ha^{-1} potassium may be considered to be optimum for getting higher yield of onion.

SUMMARY

The experiment was conducted during the year 2020 at the Horticultural Orchard, Sindh Agriculture University. Tando Jam, to evaluate the effect of different potassium rates on the growth and productivity of onion. The experiment was conducted in Randomized complete block Design (RCBD). The study comprised of six different Potassium rates including T_1= Control where no potassium application was applied, T_2= 20 kg (K) ha^{-1} (40 g SOP plot^{-1}), T_3= 40 kg (K) ha^{-1} (80 g SOP plot^{-1}), T_4= 60 kg (K) ha^{-1} (120 g SOP plot^{-1}), T_5= 80 kg (K) ha^{-1} (160 g SOP plot^{-1}), T_6= 100 kg

(K) ha^{-1} (200 g SOP $plot^{-1}$), each treatment was replicated three times. Observation was recorded for including plant height (cm), stem girth (cm), number of leaves $plant^{-1}$, weight of leaves $plant^{-1}$ (g), bulb diameter (cm), single bulb weight (g), yield $plot^{-1}$ (kg) and yield ha^{-1} (kg).

Plant height (41.70 cm), stem girth (46.8 cm), number of leaves $plant^{-1}$ (6.33), weight of leaves $plant^{-1}$(46.56 g), bulb diameter (3.33 cm), single bulb weight (49.33 g), yield $plot^{-1}$ (2.96 kg) and yield ha^{-1} (2819.2 kg) was recorded in T_1 = Control.

Plant height (45.13 cm), stem girth (49.33 cm), number of leaves $plant^{-1}$ (8.00), weight of leaves $plant^{-1}$ (51.34 g), bulb diameter (4.20 cm), single bulb weight (57.67 g), yield $plot^{-1}$ (3.46 kg) and yield ha^{-1} (3295,2 kg) was recorded in T_2 = 20 kg (K) ha^{-1}.

Plant height (46.73 cm), stem girth (51.33 cm), number of leaves $plant^{-1}$ (9.00), weight of leaves $plant^{-1}$ (53.32 g), bulb diameter (4.86 cm), single bulb weight (72.33 g). yield $plot^{-1}$ (4.34 kg) and yield ha^{-1} (4133.3 kg) was recorded in T_3 = 40 kg (K) ha^{-1}.

Plant height (47.43cm), stem girth (51.67 cm), number of leaves $plant^{-1}$ (10.00), weight of leaves $plant^{-1}$ (59.51 g), bulb diameter (5.33 cm), single bulb weight. (83.00 g), yield $plot^{-1}$ (4.98 kg) and yield ha^{-1} (4721.2 kg) was recorded in T_4 = 60 kg (K) ha^{-1}.

Plant height (48.83 cm), stem girth (53.32 cm), number of leaves $plant^{-1}$ (10.00), weight of leaves $plant^{-1}$ (63.90 g), bulb diameter (5.73 cm), single bulb weight (93.00 g), yield $plot^{-1}$ (5.58 kg) and yield ha^{-1} (5314.3 kg) was recorded in T_5 = 80 kg (K) ha^{-1}.

Plant height (52 33 cm), stem girth (55.60 cm), number of leaves $plant^{-1}$ (13.00), weight of leaves $plant^{-1}$ (66.90 g), bulb diameter (6.40 cm), single bulb weight (106.67 g), yield $plot^{-1}$ (6.4 kg) and yield ha" (6095.2 kg) was recorded in T_6 = 100 kg (K) ha^{-1}

CONCLUSION

The present study results findings that T_6 = 100 kg (K) ha^{-1} produced highest growth and yield of onion as compare to other potassium rates.

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Photosynthetic Traits of Rice Landraces (*Oryza sativa L.*) Under Drought Condition

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Abstract:
Drought stress is mainly a serious limiting factor for rice production, which creates huge economic losses by becoming more serious issue with respect to global climate change. In the view of the current situations and forecasted global food demand, it is necessary to enhance the crop productivity on the drought prone rain fed lands with utmost priority.Rice is a main staple cereal crop in the world.Climate change mainly alters the plant phyllosphere and its resource allocations. The main aim of this experiment was to evaluate the "Photosynthetic attributes on drought tolerance of rice landraces" (Oryzasativa L.). A laboratory screening, hydroponic studies and pot culture experiments were conducted in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, during 2020-2021 to investigate the Photosynthetic attributes. Rice land races, namely Anna(R) 4, 337- IC116006, 224 -IC463809 were studied. The present findings showed that drought stress reduced the photosynthetic parameters and enhanced the chlorophyll index and soil temperature in all the land races. Among the land races, Anna(R) 4 performed better under drought stress conditions when compared to other.

Keywords: Photosynthesis, chlorophyll, tolerance, landrace, leaf temperature.

INTRODUCTION

Rice is a widely consumed stable food crop in the world after wheat crop for larger part of world's human population, particularly in Asia to meet out the daily calories of a growing population (Samal et al., 2018). The consumption and cultivation of rice in worldwide is about 509.87 million metric tonnes in the year 2021 (Shahbandeh *et al*., 2021). It is estimated around 515.35 million tonnes represent an increase of 4.18 million tons i.e., 0.82 % in rice production is required around the globe for the year 2022.

Rice is positioned best among the foremost inundated crops within the world since it requires more water to grow (Kumar *et al*., 2019). At the physiological, metabolic and molecular levels, drought influences the growth and development of rice by causing numerous changes (Liu *et al*., 2017a). Rice is suited to a wide extend of settings, in spite of the fact that is semi-aquatic nature makes paddy production more efficient at high soil moisture content. However, it is necessary to adopt the rice production in the rainfed ecosystem to meet out the need of the growing world population (Gleason *et al*., 2017).

Among the abiotic stress, drought is one of the most obvious factors that limits rice yield of existing rice cultivars which do not fare well in drought-stricken circumstances. India is a home to the diverse range of rice cultivars and landraces which are lesser-known by the farmers (Biswajit *et al*., 2017) have greater potential to tolerate the water scarcity by sustaining the optimum yield. Exploring the potential of rice landraces towards the drought tolerance could be the viable alternative for increasing food production in the coming years under rainfed ecosystem (Manikavelu *et al*., 2006).

Drought can occur at any stages of the growth and development of rice. At early growth stages such as seedling stage, drought occurs results in poor crop establishment and reduced yield (Pandey *et al*., 2021). Drought stress decreases reduced growth and development of rice by negatively affecting seedling vigour, germination, leaf membrane stability, photosynthetic rate and osmolyte content (Pandey *et al*., 2015; Mishra *et al*., 2018).

Though all the stages of rice crop are sensitive to water stress conditions, the degree of sensitivity of growth stage on drought stress decides the proper growth and development and reproductive efficiency of rice crop (Binodh *et al*., 2019; Vikram *et al*., 2016). Particularly rice at reproductive stage is a critical causing yield loss up to 40 % to 60 % under drought stress (Venkatesan *et al*., 2005). Hence, it is imperative to screen the germplasm to find out the drought tolerant traits at various stages in growth like seed germination, seedling and maturity of rice (Sarkar *et al*., 2011).

PHYSIOLOGICAL RESPONSES TO DROUGHT STRESS

The chlorophyll meter (SPAD) is portable, simple, quick and non-destructive tool that measures the intensity of green colour in plants instantly and it has the potential to provide insight to the nitrogen status of crops (Makhdum *et al*., 2002). A significant correlation was obtained between SPAD readings and photosynthetic rate in soybean (Uma *et al*., 1995) and wheat species (Burke, 2010). In rice, Sivakumar *et al*. (2016) reported that SPAD readings positively correlated with chlorophyll content, photosynthetic rate and chlorophyll fluorescence (*Fv/Fm*).

The chlorophyll index is a measure of a plant's stress tolerance capabilities (Mohan *et al*., 2000). The CCM200 meter is based on the ratio of Near Infrared (NIR) to red wavelengths determines the nonlinear relationship between radiation transmission and the quantity. Radiation transmission is nonlinearly proportional to the amount of absorbing chemical in leaf tissue and linearly proportional to the compound's absorbance (Parry *et al*., 2014). The uptake of red radiation is aided by an expanded chlorophyll focus. Because these wavelengths are not consumed by photoreceptors, all plants transmit a large amount of NIR light, which is used as a form of perspective wavelength (Parry *et al*., 2010). Leaf chlorophyll meters examine how thylakoid chlorophyll communicates with incident light, and several studies have found strong links between extractable chlorophyll and non-damaging chlorophyll meter readings (Jifon *et al*., 2005).

Rice photosynthetic rate decreased due to drought stress has been thoroughly established (Ji *et al*., 2012; Lauteri *et al*., 2014; Yang *et al*., 2014). The CO_2 diffusional constraint owing to early photosynthesis is one of the key factors limiting photosynthesis. The major components restricting the photosynthesis are the CO_2 diffusional limitation due to the early stomatal closure, decreased photosynthetic enzyme activity and biochemical changes are the components linked to the synthesis of triose phosphate and a reduction in photochemical efficiency of PSII. Drought drastically reduces PSII activity in the flag leaf of rice plant (Pieters and Souki, 2005). This may be due to drought induces degradation of D1 polypeptide which lead to the inactivation of PSII reaction centre (Huseynova *et al*., 2016). Drought effect decreased the photosynthetic rate of rice has been reported (Yang *et al*., 2014).

Drought induced reduction in photosynthetic rate has been well documented (Lauteri *et al*, 2014; Yang *et al*, 2014). Extreme drought conditions limit photosynthesis because of a decreased in RuBisCO movement, which could be the component of Calvin cycle (Zhou *et al*., 2007) by advancing the ATP subordinate conformational changes, improves under the drought stress as a defensive treatment. Drought stress decreases the photosynthetic rate, water contents and transpiration rate and increases the stomatal resistance (Zhang *et al.*, 2018).

Several studies that differing in stress conditions causes difference in transpiration rate and stomatal conductance (Kamphorst *et al*., 2022). Decrease in transpiration, there is a reduction in stomatal conductance and also limits photosynthesis in rice (Sikuku *et al*., 2010). Mingchi *et al*., (2010) reported the photosynthetic rate, stomatal conductance and transpiration rate were decreased under drought stress. Drought stress hampers the plant net photosynthesis in rice genotypes (Centritto *et al*., 2009; Yang *et al*., 2014) stomatal conductance (Ji *et al*., 2012)., transpiration rate, intercellular CO_2 concentration and this might be because of decreased leaf expansion, disabled photosynthetic machinery, irregular leaf senescence, change in structure of the pigments and proteins and oxidation of chloroplast lipids (Singh *et al*., 2013).

Meena *et al*, (2004) reported that there was significant decrease in transpiration rate in maize lines under severe drought stress condition compared to control. Ramchander *et al*. (2014) observed a significantly higher transpiration rate in the rice variety Mahamay, when drought was induced at flowering stage.

Stomatal conductance is a good indicator of leaf water status (Suresh *et al*., 2012). Photosynthetic rate, stomatal conductance and transpiration rate were significantly decreased under drought stress. While at the initiation of stress treatments, the intercellular CO_2 concentration was slightly changed as observed by Ohashi *et al*. (2006) in soybean. The response pattern of gas exchange parameters and crop yield in rice imposed under drought stress at different growth stages might provide basis for selecting the drought tolerant variety to solve food crisis and stabilize yield (Sikuku *et al*., 2012). Photosynthetic rate and transpiration rate were reduced, while leaf temperature and stomatal resistance were increased under drought stress in all cultivars (Rajasekar *et al*., 2020). Reduced photosynthetic rate and stomatal conductance were observed under 100 per cent and 50 per cent drought stress over control in tomato (Bhatt *et al*., 2020).

Chlorophyll fluorescence aids in determining the impact of ecological stress on development and yield, as these characteristics are closely linked with the rate of carbon exchange (Li *et al*., 2020; Fracheboud *et al*., 2004). Light energy can drive photosynthesis can be dissipated as a heat, or remitted as light is called chlorophyll fluorescence in the chlorophyll molecules of a leaf causes a change in the efficiency of photochemistry and heat dissipation can be obtained by measuring the yield of chlorophyll fluorescence (Krishnan *et al*., 2011).

According to maximum quantum yield of chlorophyll fluorescence parameters, the water sensitivity in plant is associated with decreased photosynthetic efficiency of PSII and enhanced non – photochemical quenching (Porcel *et al*., 2015). As a result, it might be used as a reliable indicator to evaluate the metabolic or energetic imbalance of photosynthesis and yield performance across genotypes under drought condition (Araus *et al*., 1994; Araus *et al*., 1998). Water deficit significantly reduce the chlorophyll fluorescence attributes (Piper *et al*., 2007).

The surface temperature of plant leaves influences the environmental conditions and transpirational cooling that means the outward latent heat flux (Peng *et al*., 2022). A rise in leaf temperature causes a transpiration cooling (Siddqui *et al*., 2021). When there is an increase in leaf temperature, the stomata are closed and evapotranspiration stops (Wagner *et al*., 2021). An increase in leaf temperature hinders the enzymatic activity and other processes under drought stress. The photosynthetic mechanism becomes almost inactive when leaf temperature increases above a certain point (Perera *et al*., 2022).

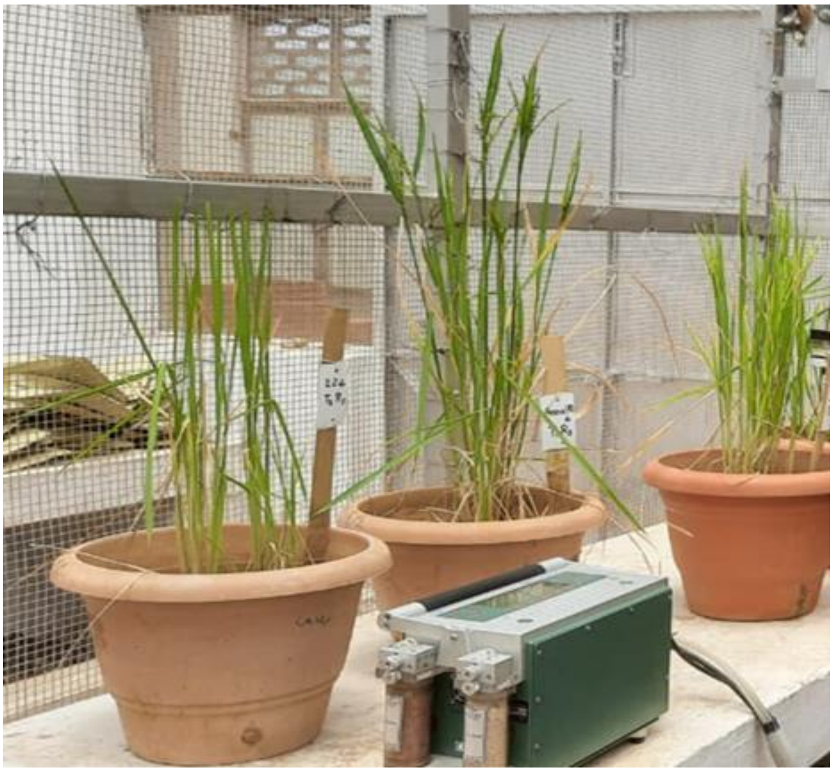
Kumar *et al*., (2015) investigated the leaf temperature in different rice varieties under drought stress during the reproductive stage and obtained that varieties Kranti and Mahamaya maintained reduced leaf temperatures than air temperature, whereas other varieties showed increased leaf temperature under drought conditions. In brinjal, Kirnak *et al*., (2019) reported that the water deficiencies increased in leaf temperature (34 °C) as compared to non-stressed plants (29.7 °C).

Relative water content (RWC) is a measure of plant water status that represents metabolic activity in tissues and may be used as a useful indicator of dehydration tolerance. The RWC of leaves is greater in the early phases of leaf growth. As the leaf grows and dry matter accumulates, the RWC decrease. The RWC is closely related with the cell volume, it might intently represent the harmony balance between water supply to the leaf and transpiration rate (Farquhar *et al*., 1989; Schonfeld *et al*., 1988). It influences the ability of the plant to recover from the stress and subsequently affect the yield and yield attributes (Lilley and Ludlow, 1996). Under drought condition, relative water content significantly decreased. At the initial stage of leaf development, the RWC is higher. It is an important indicators of plant water balance, since it represents the relative sum of water present in the plant tissues (Cramer *et al*., 2013).

RWC indicates the water status of the plants and have significant association with the stress tolerance of cell membrane stability and yield was reported by Lugojan *et al*. (2011). The relative water content of the leaf decreased under drought stress condition. Drought resistant cultivar ought to maintain more prominent relative water content compared to the susceptible ones. This trait is an adaptive feature that the certain plant species have been developed under the water stress conditions (Dhanda and Sethi, 2002; Zadehbagheri and Masoud, 2014). The leaves subjected to the drought exhibit the larger reductions in water potential and RWC (Nayyar and Gupta, 2006). Siddique *et al*. (2000) observed a concomitant increase in the leaf temperature with considerable decreased in the leaf water potential, transpiration rate and RWC on exposure to drought (Yang *et al*., 2010).

The RWC was closely related to water potential, but large differences in osmotic adjustment among genotypes cause a deviation between the two measures. The RWC was negatively correlated with spikelet sterility in two of the four seasons-controlled environment (Lafitte, 2002). Tsukaguchi *et al*. (2003) suggested that increased transpiration induces water deficit in plants during day time causing a reduced water potential leading to agitation of many physiological processes. Galmes *et al*. (2011) reported that the leaf relative water content is reduced in all accessions of tomato under drought stress condition. Kumar *et al*. (2015) also reported that a significant decreased amount of RWC under drought stress condition in pigeon pea.

In the cytosol, plants accumulate different type of natural and inorganic solutes to bring down osmotic potential in this way keeping up cell turgor (Inan *et al*., 2004). Under drought stress, the maintenance of cell turgor may be accomplished by the method of osmotic adjustment because of the gathering of sucrose, proline, solvent sugars, glycine betaine, carbohydrates and different solutes in cytoplasm improving water uptake from dry soil. Under drought stress, the procedure for the accumulation of such solutes is called as osmotic adjustment that firmly depends on the rate of plant water stress (Basra *et al*., 2003). A significant physiological response of plants under drought is the capacity to maintain turgor pressure by decreasing osmotic potential as tolerance mechanism (Maisura *et al*., 2014).



CONCLUSION

The selected genotypes were categorized into tolerant, moderately tolerant and susceptible. Accordingly, the genotypes were observed for the morphological, physiological, biochemical characters and yield components. The summary of present findings is presented here under. The conclusions arrived from the present study are summarized below.

- The most significant findings from this research are the identification of tolerant rice landrace *viz.*, 337- IC116006 performed better under drought stress as compared to susceptible rice landrace 224- IC 463809.
- The physiological traits *viz.*, photosynthetic rate, stomatal conductance, transpiration rate, chlorophyll fluorescence, chlorophyll index, relative water content, leaf temperature and osmotic potential were considered as indicators of drought tolerance were observed higher in the tolerant landrace 337-IC116006 as compared to susceptible landrace 224-IC463809.
- The gas exchange parameters revealed that thephotosynthetic rate, stomatal conductance and transpiration rate were higher in the landrace 337-IC116006.

- Higher chlorophyll index (SPAD), chlorophyll fluorescence (*Fv/Fm* ratio) and Relative water content (RWC) with low leaf temperature with low osmotic potential were observed in the landrace 337- IC116006 than the landrace 224- IC463809.

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Vermiculture Technology Promotion Through on Farm Validation of Vermicompost in Asossa Zone of Western Ethiopia

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Abstract:
A field experiment was conducted for two consecutive cropping seasons (2020- 2021) on farmers' fields in the Asossa zone of Benishangul Gumuz Regional State. The objective of this study was to promote vermicompost or vermiculture technology on the farmer's field. The treatments included three selected combinations of organic and inorganic nutrient sources, including NPS, NPS plus 100% N from vermicompost, and NPS plus 100% N from Urea. The design was replicated over the farmer's field. Results showed that from 2020 to 2021, the vermicompost technology was demonstrated on 15 farmers' fields with plot size 10mx10m planted with hot pepper, maize and sorghum crops. The results indicated that all crops treated with recommended NPS plus 100% N from vermicompost performed better than NPS alone and NPS plus N from Urea. The application of recommended NPS plus 100% of N from vermicompost based on N equivalency was higher in grain yield of maize by 80.2% and 51.7% compared to the control N and application of recommended NPS plus 100% of N from inorganic fertilizers, respectively. Additionally, the application of recommended NPS plus 100% of N from vermicompost based on N equivalency was higher in grain yield of sorghum by 44.8% and 16.2% compared to the control N and application of recommended phosphorous plus 100% of N from inorganic fertilizers, respectively. Therefore, it is better to scale out the vermicompost/vermiculture technology on wider areas of the same agroecologies of Benishangul Gumuz Regional State.

Keywords: vermicompost, vermiculture, based on equivalency, grain yield, promotion, technology

INTRODUCTION

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. Continuous nutrient depletion and low soil fertility have not only led to the development of integrated soil fertility management technologies that offer the potential for improving soil fertility in Africa (Tilahun, 2003), but almost simultaneously caused extensive studies on nutrient balance in various African farming systems. The application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and the nutrient needs of crops are according to their physiological requirements and expected yields (Ryan, 2008). The application of inorganic fertilizer is to increase crop yield, but it becomes a chronic problem due to its cost and deterioration in soil physical, chemical, and biological properties of the soil. And also, it cannot full fill long-term productivity on many soils since they are not effective in maintaining soil fertility. The application of bio-fertilizers such as vermicomposts has been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil Cation Exchange Capacity (CEC) and increasing crop yields (Hargreaves *et al*., 2008).

Vermicomposting has been considered a suitable technology for developing countries, especially at the household and community level as it is a simple and natural technology that does not require sophisticated machinery, high capital investment, and frequent process monitoring (Lim *et al*., 2016). Zucco *et al*. (2015), reported that vermicompost is often used in sustainable farming systems to improve soil physical properties, provide plant nutrients, and recycle organic wastes and has been shown to increase plant growth and crop yields. The solely recommended inorganic fertilizer has not further improved crop production and it aggravates for soil acidity problem of Western Ethiopia. Therefore, to increase crop production in this area, there was a need to integrated soil fertility management through verm-culture/earthworm technology promotion in the Region. This study was conducted to promote vermiculture technology through on farm Validation of Vermicompost, at Mao-komo and Asossa Zone, Western Ethiopia

MATERIAL AND METHODS

Description of the Study Sites

The experiment was conducted in Benishangul Gumuz Regional State, at Asossa Agricultural Research Center (AARC) research farm in the 2016/17 main cropping season under rain-fed field conditions. Benishangul Gumuz Regional State is geographically located at $9^{O}30'$ to $11^{O}39''$ N latitude and 34^{O} 20' to 36^{O} 30''E longitude covering a total land area of 50,000 square kilometers. The study site is located at 10^{O} 02' 05'' N latitude and 34^{O} 34' 09'' E longitudes. The study area is situated east of Asossa town and West of Addis Ababa about 4 km and 660 km distance, respectively. Asossa has an unimodal rainfall pattern, which starts at the end of April and extends to mid-November, with maximum rainfall received in June, to October. The total annual average rainfall of Asossa is 1275 mm.The minimum and maximum temperatures are 16.75^{o}C and 27.92^{o}C, respectively. The dominant soil type of the Asossa area is Nitosols with the soil pH ranging from 5.0 to 6.0.

Site and Beneficiary Selection

The participating farmers were selected by the Office of Agriculture and rural development respective woredas of Asossa and Bambasi). Beneficiary farmers were selected based on the criteria and objectives of the operational research for the technology dissemination project and the interest of farmers to participate in the demonstration trials. In addition, the safety net beneficiaries and disadvantaged households (youths and women-headed households) were the main focus of the activity.

Materials and Agronomic Management

The earthworms were demonstrated and popularized in two selected districts (Asossa and Bambasi) on. Three treatments with three tests (T1=Recommended inorganic nitrogen (Urea) plus Recommended NPS, T2=100% of vermicompost based N equivalence plus Recommended NPS and T3=Negative control of nitrogen fertilizer Recommended NPS) were replicated across the five farmer's field for each testing crop of the respective weredas according to research procedure or phase. Popularization of small-scale vermiculture/earthworm technology demonstration in farmers was implemented on selected farmers Crops were planted as demo plots across the farmer's field of the respective weredas. All plots uniformly received NPS as basal application during planting for each test crops. The experiment was replicated across farmers field with three treatments. The blocks were separated by a 1.5 m wide open space where as the plots within a block were separated by a 0.75 m wide space. Soil bunds were constructed around each plot and around the entire experimental field to minimize nutrient, water movement, and cross contamination from plot to plot. Weed control was achieved manual by hand picking. Crop growth was then monitored until harvest.

Training and Awareness Creation

Farmers were trained before how they can multiply earthworms. The bin is constructed from locally available materials. A total of 110 male and 72 female beneficiary farmers were participated on training and the earth worm technology was delivered for those tried farmers. As part of the intervention activities, training on verm-compost and earthworm was given to farmers, DAs and experts. During the training, we discussed with farmers to give the earthworm for other farmers, so redistribute to other new beneficiaries in the next production season and it will be continued in the form of a revolving fund.

Field Day

In the field day and experience sharing farmers, development agents (DAs), experts, heads of agricultural and rural development office and researchers were participated. Finally, to evaluate the performance and final outputs of the vermicompost and share the lessons with different stakeholders' field days were organized in the fields of beneficiary farmers. On the field days farmers, development agents (DAs), experts, heads of the agricultural and rural development office, woreda administrators, researchers from Asossa Agricultural Research Center and other stakeholders from Bambasi.

Data Collection

Grain yield and yield components of sorghum, maize and hot pepper, farmers feedbacks were collected. The grain and yield components data were collected using data collection sheets and only the grain yield for maize and sorghum, and fresh red fruit weight and dry fruit weight based its economic importance. The feedbacks were collected using checklist by conducting group discussions and key informant interviews.

Yield advantage was calculated by:

$$\text{Yield advantage \%} = \frac{\text{Yield advantage of vermicompost} - \text{Negative control of N}}{\text{Negative control of N}} \times 100$$

Yield advantage of the demonstrated varieties was calculated using

Data Analysis

The collected agronomic data was analyzed using descriptive statistics and excel. The grain yield and fruit weight data were analyzed using excel and presented using figures.

RESULT AND DISCUSSION

Current Status of Vermiculture for Vermicompost Production Under Small-Scale Farmers in Assosa Zone

The demonstration and popularization of earthworm technology for vermicompost production was undertaken by Asossa Agricultural Research Center in collaboration with NGOs, SLM PProject 2 and the Asossa Environmental Protection, Association. Pre-scaling up of small-scale vermiculture technology demonstration in farmers were implemented on selected farmers. Consequently, the Asossa Environment Protection Association (Local NGO) and SLM project promoted and demonstrated the advantage of vermiculture with the collaboration of the Asossa

Agricultural Research Center through the distribution of three earthworm species that have been known in the region. Overall vermiculture focused training was delivered to farmers across the Weradas of the region by the Asossa Agricultural Research Center. Vermiculture unit constructed from locally available materials (Bamboo trees) including bin. About 200 kg of worms were multiplied and distributed to more than 1500 farmers (0.5 kg/bin). A total of 110 male and 72 female beneficiary farmers participated in verm-compost technology. In the first year, vermicompost was produced using the selected local worm and *E. fetida* (standard check) from the already recommended source and proportion in the Asossa Agricultural research center. The 50 - 70 farmers per kebeles can be engaged during field demonstrations. In addition, these members subsequently trained other farmers and gave their earthworms to other farmers to distribute to other group members. The mini field day was organized across the Weredas for the vermiculture/earthworm technology promotion.

Pictures 1: Earthworm multiplication with locally available feeding materials

Pitures 2: Practical and theoretical training of farmers on bin construction from locally available materials

The trained farmers have started to construct the bins for earth worm/vermicompost technology use. The small-scale farmers have been starting to use vermicompost as source of Urea fertilizer and planted maize, hot pepper and sorghum.

Pictures 3: Field performance of the crops under field condition

Farmers field day

As part of the intervention activities, training on verm-compost and earth worm was given to farmers, DAs and experts. Finally, in order to evaluate the performance, share the lesson with different stakeholders' field day and experience sharing were organized in the fields of beneficiary farmers. In the field day and experience sharing famers, development agents (DAs), experts, heads of agricultural and rural development office, researchers were participated. The vermicompost demonstrated were compared based on farmers preferences and the field data recorded and analyzed by descriptive statics. The participant farmers preferred vermin compost plus NPS fertilizer during the field day and their first choice.

List of participants on the day of field day								
Farmers			Researchers			Expert and development agents		
male	women	total	male	Women	total	Male	women	Total
30	15	45	5	2	7	3	1	4

Pictures 4. During farmers field day conducted under field condition

The Effect of Vermicompost on Hot Pepper at Bambasi and Asossa Destricts

The highest red fresh fruit weight (2155.8 kg/ha) and red dry weight fruit weight (1585.9 kg/ha) were obtained under the application of 100% based N equivalence of vermicompost (7.5-ton ha^{-1} vermicompost), while the lowest red fresh fruit weight (1296.5) and red dry fruit weight (977.7 kg/ha) were recorded under the negative control of N. Comparing the red fresh fruit weight showed that 100% based N equivalence of vermicompost application resulted in 66.3% and 50.6% more red fresh fruit weight as compared to the control treatment and recommended inorganic N respectively (Figure 1). On the other hand, application of vermicompost T3 increases the red dry fruit weight by 62.2% over the negative control plot. As compared to the recommended inorganic N, the mean value of the weight of red dry fruit of hot pepper increased by 43.9% for T3 at Asossa and Bambasi Destricts. These results are similar to previous findings of Pavan AS (2013), who reported that chili yield and fruit weight increased with increasing quantity of vermicompost. The reason might be that vermicompost which is a rich source of macro and micro nutrients, enzyme and growth hormones that promoted growth of plant as well as fruit yield. These results are similar with that of (Arancon *et al.*, 2004) who found that pepper produced greater fruit yield with the application of vermicompost.

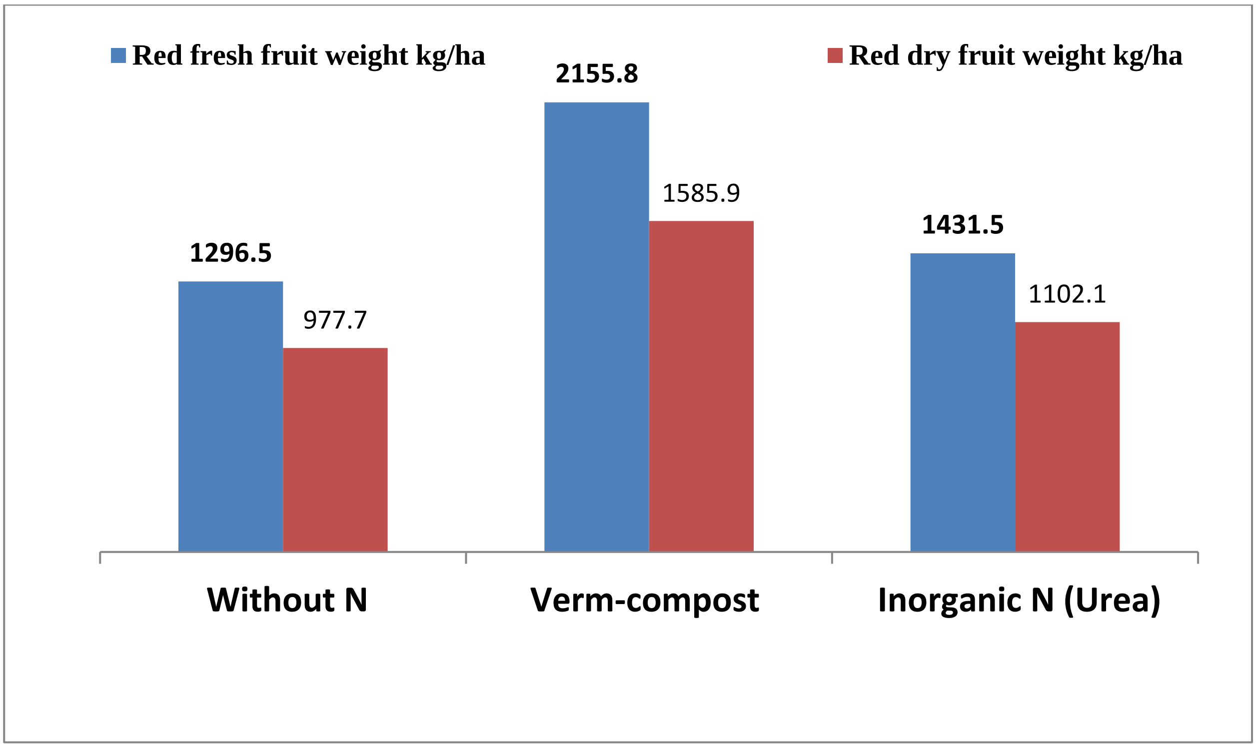

Figure 1. Effect of vermicompost and inorganic N on fresh fruit weight and dry fruit weight of hot pepper

The highest red fresh fruit weight and red dry weight fruit observed under vermicompost fertilizer could be due to vermicompost has capacity to supply both macro and micronutrients in the soil for optimum plant growth which might have enhanced growth and development of crop as compared to the recommended N and P and control or without fertilizer (Harris *et al.*, 1990). These plant nutrients are adsorbed on the humic acid molecules and are released slowly and gradually into the soil solution and made available for plant growth and development processes (Guiterrez 2007).

The Effect of Vermicompost on Maize at Bambasi and Asossa Destricts

The application of recommended NPS plus 100% of N from vermicompost based on N equivalency (5-ton ha^{-1} vermicompost) was higher in grain yield of maize by 80.2% and 51.7% compared to the control N and application of recommended NPS plus 100% of N from inorganic fertilizers, respectively. The same founding was reported by Abdissa *et al*. (2018), who reported the found interaction effect of lime, vermicompost and mineral P fertilizer had a highly significant effect on the 1000-seed weight of maize with higher mean 1000-seed weight was obtained with the application of 2.5 t vermicompost ha^{-1} and 40 kg P ha^{-1} and lime, which might be due to the synergistic effects of the combined effects of vermicompost and lime in improving growth and grain filling of maize, the physicochemical and biological soil properties. The yield advantage relative to the control (unfertilized) of N treatment was 80.2% (Figure 2) indicating the depletion of the soil and its strong response to fertilizer application. This is an indication that the integrated use of organic and inorganic nutrient sources of fertilizers was advantageous over the use of inorganic fertilizer alone and also result in synergy and improved synchronization of nutrient release and uptake by the crop. Combined application of both organic and inorganic sources to take care of maize nutrition more effectively leads to better productivity (Yadav *et al*., 2016).

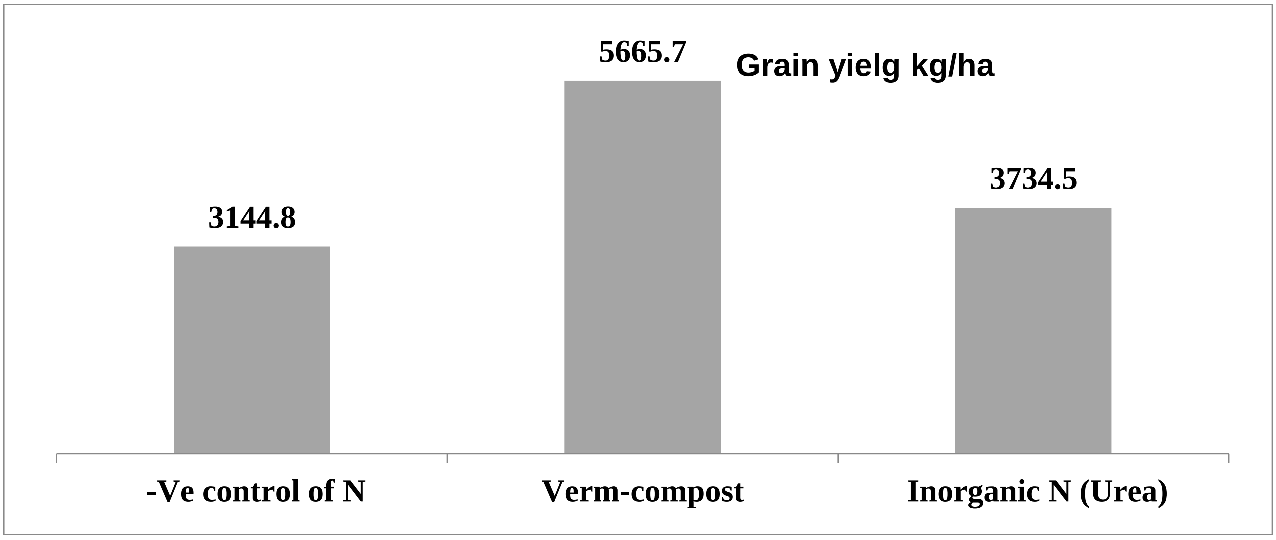

Figure 2 Effect of vermicompost and inorganic N on grain yield of maize at Asossa and Bambasi Districts

The Effect of Vermicompost on Sorghum at Bambasi and Asossa Destricts

The application of recommended NPS plus 100% of N from vermicompost based on N equivalency (3-ton ha^{-1} vermicompost) was higher in grain yield of sorghum by 44.8% and 16.2% compared to the control N and application of recommended phosphorous plus 100% of N from inorganic fertilizers, respectively. Similar finds were reported by Cavagnaro (2014), who reported that organic amendments have improved soil physical, chemical, and biological properties, providing essential plant nutrients to stimulate plant growth and yield. Similar funds by Makinde and Ayoola (2010) concluded that high and sustainable crop yields are only possible with the integrated use of mineral fertilizers and organic matter. According to a study by Dawar *et al*. 2022 observed that the height of the maize plant treated with vermicompost plus NPK was greater than that of the vermicompost or minerally fertilized plot. According to Chimdessa and Sori (2020), the addition of 3 $t \cdot ha^{-1}$ of vermicompost increased grain production by approximately 66.88% compared to the treatment using 100 $kg \cdot ha^{-1}$ of the locally advised NPS rate. Additionally, past research indicated that higher vermicompost quality and vermicompost levels boosted grain Dawar *et al*. 2022. Similarly, Sigaye *et al*. (2020) found that grain yield responded well when organic fertilizer and mineral fertilizer were applied together.

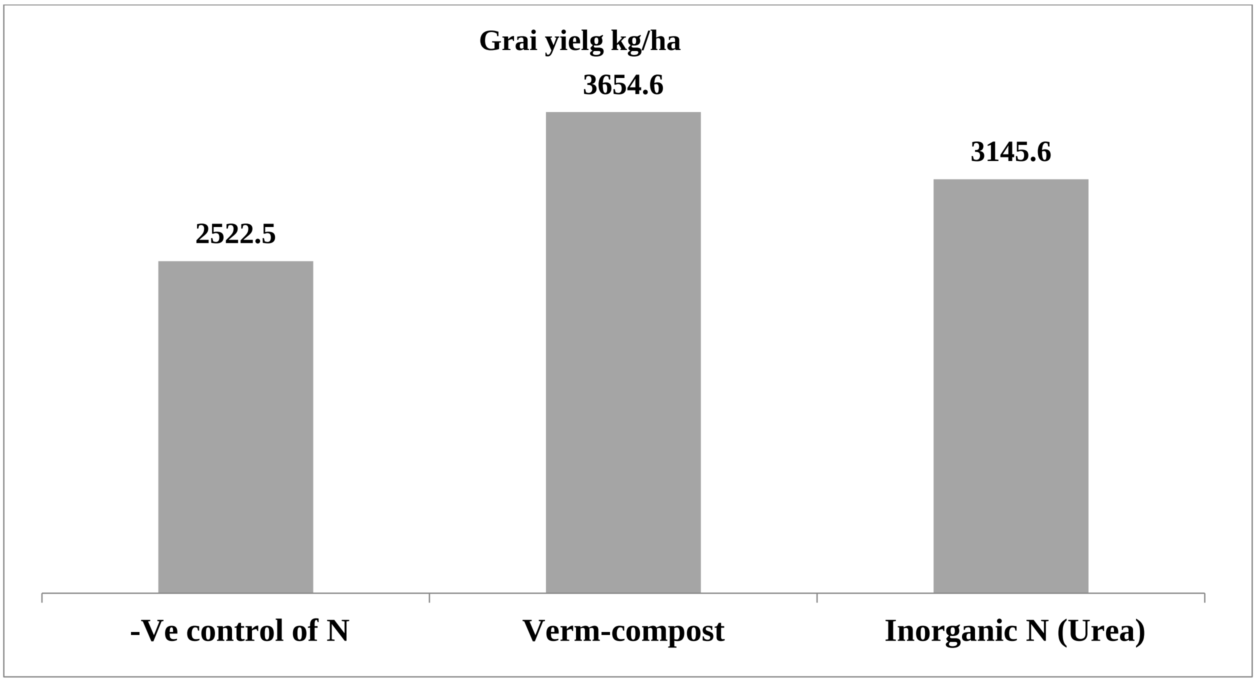

Figure 3 Effect of vermicompost and inorganic N on grain yield of sorghum at Asossa District

CONCLUSION AND RECOMMENDATION

Vermicompost improved the red fresh weight, red dry weight of hot pepper, grain yield of maize and grain yield of sorghum, while increasing soil pH and reducing exchangeable acidity resulting in high grain yield of hot pepper, maize and sorghum. The application recommended NPS plus 100% of N from vermicompost based on N equivalency revealed superior fruit weight of hot pepper, and grain yield of maize and sorghum as compared with the application of recommended NPS plus recommended inorganic N. Thus, for the sustainability of crop production in western Ethiopia, rather than using inorganic fertilizer, the combination of organic sources with inorganic ones would be beneficial in terms of crop and soil productivity. Popularization and on-farm validation of vermicompost technology were essential components of disseminating the best technologies to farmers to boost the production and productivity of small-scale farmers per unit area in the study sites. The obtained yield advantage of vermicompost was significantly better than the inorganic N. Moreover, farmers who participated in the vermicompost technology have gotten higher income per production season from the sale of green hot pepper and dry red-hot pepper. From the results of it can be concluded that application recommended NPS plus 100% of N from vermicompost based was superior for increased productiviety and sustabability of crop production. Thefore application recommended NPS plus 100% of N from vermicompost can be recomendede for scale up study area and similar its agro-ecological areas.

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Acoustic Comfort Evaluation of Residence that Uses Portable Electricity-Generating Plants

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Abstract:
The response of various sectors of the Nigerian economy to the epileptic state of power supply from the Nigerian electricity grid has greatly contributed to the acquisition and use of mobile power generation equipment as an alternative energy source. This study examined the acoustic impact of power generation facilities on residential environments in the greater Abeokuta area. The total noise emitted by each portable generator was measured at various distances of 1 meter each, starting at 1 m from the portable generator and up to 5 m from the previous measurement point. Measurements were taken 15-30 minutes before and after the operation of the portable power plant and 30-60 minutes during operation. Data was collected using a tape measure, a digital stopwatch and a GM 1352 sound level meter. The average results for noise emission during use of the generator were maximum (mean = 83.93 dBA, SD = 1.35) and minimum (mean = 71.72 dBA, SD = 0.85) at a distance of 1 m, which was much higher than the average environmental noise level before (mean = 47.36, SD = 0.75) and after (mean = 47.63, SD = 0, 75) generator operation. Analysis of noise level intensity for household acoustic comfort using the United States Department of Housing and Urban Development's recommended categories of typical noise levels for residential areas revealed that the outdoor noise levels of the assessed environment before and after use of portable power generation equipment were within $L_{Aeq} \leq 49$ dBA and $49 < L_{Aeq} \leq 62$ dBA, which represent clearly and normally acceptable noise level limits for residential areas. However, the noise levels modified to ranges within of $62 < L_{Aeq} \leq 76$ dBA (normal) and $L_{Aeq} > 76$ dBA (clearly) unacceptable noise level when using portable power generators. This means that power plants pose a noise nuisance to the outside of the houses in which they are used to supply electricity, thereby affecting the acoustic comfort of that environment.

Keywords: Residence, electricity-generating, noise, acoustic comfort.

INTRODUCTION

An environment is considered comfortable when there are few or no annoyances or distractions during work or leisure activities, including environments that may physically or psychologically impair activity in that environment (Azodo and Adejuyigbe, 2013). According to Olokoaba (2005), noise is detrimental to both human health and the environment's ability to maintain comfort. Due to technological development, noise is one of the physical pollution factors that have a negative impact on human health. Noise is a stressor of such importance that it is an integral part of our environment, so much so that the term noise pollution refers to the dangers of noise in addition to the serious consequences of this modern development. (Azodo and Adejuyigbe, 2013).

According to Katsil (1998), noise pollution increases irritability in men, and the effects are multiple and interrelated. Noise disturbs people not only at home but also in inner cities, on the street and at various workplaces (van der Merwe, 2013). Urban centres are characterized by noisy environments associated with activity, which is why some people prefer to live in remote locations (Babawuya et al., 2016). Noise pollution in our environment is increasing rapidly and is one of the greatest threats to the quality of life at all levels (Okoro, 2014; Khaki et al., 2010). According to FEPA (1995) and WHO (1980), noise is produced when the sound power of a vibrating body exceeds levels considered safe for the environment. Noise fades away from its source as it spreads to more distant air particles (van der Merwe, 2013). When classifying noise by type, it falls into two main categories: industrial noise and residential noise (Jackson, 1990).

Residential noise has been described as noise emanating from any source other than factories (Muhammad et al., 2008). All citizens and residents are exposed to noise pollution from their homes as they return home from their daily activities to rest and recharge for the next day's challenges. The utilization of portable power generation systems demonstrates the importance of power generation systems in household activities. The role of portable power generation systems as an alternative source of energy contributes significantly to comfort, mechanization of household chores, joy and enjoyment of life. Studies have shown that the use of generators contributes significantly to environmental noise pollution (Iqbal and Lodhi, 2014; John and Dewan, 2015). If left uncontrolled, generator noise becomes a major problem at measured levels above 100 dBA (Aaberg, 2007).

The importance of residential generators must be within healthy dose exposure rates, regardless of the noise they generate (Azodo et al., 2018a). A review of the literature shows that quiet is a fundamental environmental health factor in residential areas, having a positive impact on residents' standard of living and well-being (Azodo et al., 2018a). Ohwovoriole et al. (2016) added that environments characterized by objectionable noise interfere with people's vital activities. The wide range of exterior noise levels demonstrated by Goodfriend (1977), ranging from the characteristic noise conditions of a busy city center to the quiet of the wilderness, shows that acoustic comfort is achievable. According to Mohd (2011), noise exposure has a greater impact on human health than other environmental stimuli.

Different responses from different sectors of the Nigerian economy to the epileptic power supply situation in the country contributed significantly to the import rate of power plants. The acquisition and use of power generation facilities as alternative energy sources are increasing year by year and thus contribute significantly to noise pollution in the environment (Okoro, 2014). Roughly divided into engines, alternators, fuel systems, exhaust voltage control systems, control panels, and frames, generators are useful devices made up of many parts.

In engine-driven generators, the heat and pressure produced by the combustion of fuel mixed with air are converted into mechanical energy by the combustion process and parameters affecting combustion (Kass, 2008). Engine reciprocation produces noise and vibration (Aaberg, 2007). A rotary generator produces electricity through the mechanical movement of an internal combustion engine's piston-crank system and the pressure fluctuations caused by the exothermic reaction of the hot expanding gas (high-temperature, high-pressure oxidized fuel) in the combustion chamber. Each vibration and movement produce a series of alternating stages of compression and rarefaction that travel through the air and are perceived by the human ear as sound. Studies have shown that users of portable power generation systems are more likely to install them near their homes, where they are exposed to noise and vibration (CPSC, 2006; Ashmore and Dimitroulopoulou, 2009). On the other hand, the proximity of power generation facilities can introduce noise into living spaces and affect the acoustic comfort of surrounding households (Azodo et al., 2018a).

The intensity of the sound produced by devices depends on the receiver's distance from the source, the type of environment and the type of noise source (Khaki et al., 2010). The principle of sound propagation generally consists of three interconnected elements: the source, the transmission path and the receiver. The transmission path is always via a material medium or outdoors to the recipient. This can be continuous or intermittent, but it can also be of low or high frequency, making it undesirable for normal hearing (Chattomba, 2010). Chattomba (2010) stated that most transient hearing loss occurs within the first two hours after exposure. The effects of noise on the ears are of three categories: acoustic trauma, permanent and transient hearing loss (Melamed et al., 2001). Noise exposure can also be a serious source of stress on the auditory and non-auditory systems, as well as the nervous system of exposed individuals. Emphasis on the impact of noise levels beyond 70 to 75 decibels as found in the world health organization's exposure limit explained that the health challenges beyond these limits causes rise in the blood pressure, challenges with emotions and behavioural effect. Prolonged exposure to high levels of noise above 85 dBA can cause hearing loss (Khaki et al., 2010).

Chronic exposure to noise in residential, work, and some recreational settings can result in numerous health effects (Camp and Davies, 2012). The sound level meter measures the average reading over a period of time, t, in dB. The running time (t) is displayed at the bottom of the screen (Adie et al., 2012). When sound is generated by a source, its decibel level drops with respect to the distance from that source (LSA, 2006). The unresolved scourge in limited access to quality and quantity electricity in the nation with a significant number of households own and operate generators due to these shortfalls with it attended it serves as power main source of power supply triggered this research. Therefore, this study measured and evaluated the acoustic comfort of residence that uses portable electricity-generating plants according to the United States Department of Housing and Urban Development (HUD) to analyse the outdoor noise of various residents.

MATERIALS AND METHOD

This cross-sectional study of noise levels from electricity power generation facilities used by residents of Abeokuta was selected using a systematic random sampling technique. A total of 150 portable generators were evaluated in the homes visited. Noise emission sampling data collection was conducted from households where the portable power generation systems were installed on residents' balconies, including bungalows and multi-storey buildings. The noise emission of each mobile power generation unit was measured at different distances of 1 m from the previous measurement point, starting at a distance of 1 m from the power generation unit. The vertical measurement height considered for sound level measurements was 1.5 m above the floor. The maximum and minimum distances from measurements were 5 meters and 1 meter, respectively. Measurements were taken at three different times during the run (30–60 min after the start of the load run time) and 15–30 min before and after the generator was switched on and off, respectively. The data collection period is based on the routine use of the informed portable power generation system between 8:00 p.m. and 11:00 p.m.

The noise levels emitted by the outdoor portable generators of the various houses surveyed were measured using a Benetech digital sound level meter model GM 1352 (Shenzhen Jumaoyuan Science and Technology Co., Ltd., China) (Figure 2). The factory calibrated digital noise level meter from Benetech is preset to a slow response mode with an accuracy of 1.5 dB and a measurement resolution of 0.1 dB in the frequency range from 31.5 Hz to 8 kHz and measures noise levels from 30 to 130 dBA. Benetech digital sound level meters are equipped with a A-weighting noise level scale as standard adapted for industrial and environmental noise emissions assessment because it correlates with human auditory perception and response.

A digital stopwatch model PC-396 (Shenzhen Super Deal Co., Ltd., China) (Fig. 3) was used to measure the time of the measurement intervals. Sound levels were measured and recorded at five distances (1 - 5 m) from each residential portable generator, with two 2-minute intervals at each point, yielding 20-minute readings for each point measured distance from the generator. Sound level measurements include maximum and minimum noise level values in dB. The measured distance was determined with a retractable tape measure model B300-AG (Shangqiu Dinglian International Trade Co., Ltd.) (Figure 1).

Figure 1:
A measuring tape

Figure 2:
Benetech digital sound level meter

Figure3:
A digital stopwatch

The owners of the portable power generation systems used in the research were contacted to obtain their consent to include these systems in the study sample. Only where permission was granted was included in this study. The objective of the study was provided for the proposed households. The noise levels obtained from the evaluated portable power generation systems were compared to typical noise level scales and US Department of Housing and Urban Development (HUD) recommended residential noise levels to analyze outdoor noise for various occupants. The HUD categories of the typical noise levels were $L_{Aeq} \leq 49$ dBA for clearly acceptable, $49 < L_{Aeq} \leq 62$ dBA for normally acceptable, $62 < L_{Aeq} \leq 76$ dBA for normally unacceptable and $L_{Aeq} > 76$ dBA for clearly unacceptable noise levels (Babawuya et al., 2016). The analysis was performed using the Statistical Package for Social Science Version 20.0 and the Microsoft Office Excel version 2010.

RESULTS AND DISCUSSION

Of the 150 households visited with research proposals and permits to assess the noise emission level of their portable power generation system, only 93 agreed and kept their appointments for portable power system measurements. This resulted in a response rate of 62%, which was used as 100% in this study. A sample summary of noise emission levels, statistically analyzed and recorded for each of the 93 homes, is presented as the mean, standard error of the mean, standard deviation, minimum, and maximum (Table 1).

Table 1. Statistical analysis of the portable electricity-generating plant noise emission level samples obtained at each of the ninety-three residences

Measurement distance (m)	Minimum (dBA)	Maximum (dBA)	Mean (dBA)	Standard error of mean (dBA)	Standard deviation (dBA)
Noise level before portable electricity-generating plant usage					
1	34.10	75.90	47.36	0.75	10.27
2	34.60	75.00	47.72	0.64	8.75
3	34.20	73.80	47.38	0.67	9.15
4	34.10	75.80	46.18	0.69	9.39
5	34.00	80.30	47.35	0.74	10.11
Noise level during portable electricity-generating plant usage					
1	40.00	117.90	83.93	1.35	18.42
2	42.00	118.00	81.92	1.29	17.57
3	40.50	118.00	77.25	1.10	14.99
4	41.70	117.60	74.70	0.98	13.40
5	41.90	114.90	71.72	0.85	11.62
Noise level After portable electricity-generating plant usage					
1	34.00	80.80	47.63	0.75	10.25
2	34.40	90.60	45.96	0.71	9.74
3	34.00	96.60	46.23	0.71	9.66
4	34.00	97.40	45.96	0.73	9.94
5	34.00	99.60	47.42	0.94	12.85

Outdoor environmental noise level results of the various portable electricity-generating plants assessed in different households before and after the portable electricity-generating plant usage time showed that both maximum and minimum noise levels obtained fell within the noise level ranges of LAeq ≤ 49 dBA for clearly acceptable and 49 < LAeq ≤ 62 dBA for normally acceptable at the five different distances (1-5 meters) from which the measurements were taken (Tables 2 and 3; 6 and 7). Powering on the portable electricity-generating plant showed that there was a change in the noise level of the various assessed household during the portable electricity-generating plant usage time. The measured noise level changes observed showed that most outdoor environments changed to 62 < LAeq ≤ 76 dBA and LAeq > 76 dBA, which are normally unacceptable and unacceptable noise level ranges for recommended noise level for residential areas (Tables 4 and 5). This study showed that in most households the measurement during portable electricity-generating plant usage is higher than the clearly unacceptable noise obtained in the residents assessed. The values that were within the noise levels of LAeq > 76 dBA were 64 (68.8%), 49 (52.7%), 33 (35.5%), 26 (28.0%) and 17 (18 .3%) at distances of 1, 2, 3, 4 and 5 meters were shown to be above the 70-decibel limit for outdoor noise levels set by the World Health Organization and above the 70-75 dB (A) level accepted by the Environmental Protection Agency (EPA). Also, when comparing with the allowable noise levels specified in the Environmental Protection Act, the Residential Area Code, during the day from 6 a.m. to 9 p.m. and at night from 9 p.m. to 6 a.m., the obtained results were 55 and 45 decibels, respectively (Okoro, 2014). The noise level data values analyzed correspond to a range of apparently acceptable and normally acceptable noise levels observed only before and after use of portable power generation systems. This study agrees that noise from power plants increases the average ambient noise level and the A-weighted noise level of the environment in which the portable power generator operates (Okoro, 2014). This study also agreed with the study by Babawuya et al. (2016) agree that high noise levels resulting from the use of portable power generation systems affect the outdoor activities. This means that the power plants that provide the electricity are located outside the house, which leads to noise pollution and acoustic comfort of homes.

Table 2. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended before usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	36 (38.7%)	43 (46.2%)	14 (15.1%)	0 (0%)
2	35 (37.6%)	46 (49.5%)	12 (12.9%)	0 (0%)
3	36 (38.7%)	43 (46.2%)	14 (15.1%)	0 (0%)
4	38 (40.9%)	42 (45.2%)	13 (14.0%)	0 (0%)
5	33 (35.5%)	47 (50.5%)	13 (14.0)	0 (0%)

Table 3. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended before usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	90 (96.8%)	2 (2.2%)	1 (1.1%)	0 (0%)
2	92 (98.9%)	1 (1.1%)	0 (0%)	0 (0%)
3	90 (96.8%)	3 (3.2%)	0 (0%)	0 (0%)
4	91 (97.8%)	2 (2.2%)	0 (0%)	0 (0%)
5	90 (96.8%)	1 (1.1%)	1 (1.1%)	1 (1.1%)

Table 4. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended during usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	6 (6.5%)	0 (0%)	23 (24.7%)	64 (68.8%)
2	1 (1.1%)	0 (0%)	43 (46.2%)	49 (52.7%)
3	1 (1.1%)	0 (0%)	59 (63.4%)	33 (35.5%)
4	1 (1.1%)	0 (0%)	66 (71.0%)	26 (28.0%)
5	1 (1.1%)	0 (0%)	75 (80.6%)	17 (18.3%)

Table 5. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended during usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	2 (2.2%)	1 (1.1%)	48 (51.6%)	42 (45.2%)
2	2 (2.2%)	2 (2.2%)	48 (51.6%)	41 (44.1%)
3	3 (3.2%)	0 (0%)	64 (68.8%)	26 (28.0%)
4	2 (2.2%)	1 (1.1%)	70 (75.3%)	20 (21.5%)
5	3 (3.2%)	2 (2.2%)	84 (90.3%)	4 (4.3%)

Table 6. Maximum noise level of portable electricity-generating plants analysis for residential areas recommended after usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	36 (38.7%)	37 (39.8%)	18 (19.4%)	2 (2.2%)
2	40 (43.0%)	40 (43.0%)	12 (12.9%)	1 (1.1%)
3	46 (49.5%)	36 (38.7%)	9 (9.7%)	2 (2.2%)
4	40 (43.0%)	42 (45.2%)	10 (10.8%)	1 (1.1%)
5	43 (46.2%)	39 (41.9%)	0 (0%)	11 (11.8%)

Table 7. Minimum noise level of portable electricity-generating plants analysis for residential areas recommended after usage

Distance of measurement from the portable electricity-generating plant (Meters)	Clearly acceptable N (%)	Normally acceptable N (%)	Normally unacceptable N (%)	Clearly unacceptable N (%)
1	90 (96.8%)	3 (3.2%)	0 (0%)	0 (0%)
2	92 (98.9%)	1 (1.1%)	0 (0%)	0 (0%)
3	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)
4	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)
5	93 (100.0%)	0 (0%)	0 (0%)	0 (0%)

CONCLUSION

The results of this study on the acoustic comfort levels of users of power generation system revealed that the external noise level of the environment studied before and during the operation of the portable electricity-generating plant was well within the acceptable range (clearly and normally acceptable noise level limits within $LAeq \leq 49$ dBA and $49 < LAeq \leq 62$ dBA, respectively) for the noise level of the residential area, which then changed to normal ($62 < LAeq \leq 76$ dBA) and clearly ($LAeq > 76$) unacceptable noise level ranges for the operation of power generation system. Considering that the residential sector encompasses many households is a sector for recreation or relaxation in the economic system, as people retire to their various homes for relaxation, refreshment, and preparation for the next day's activities, and in other places a degree of rest and acoustic comfort to achieve this purpose. For portable power generation systems that employ efficient sound absorption materials to lower noise emissions to acceptable levels, sound insulation is necessary. This is because both the acoustic and non-acoustic effects of noise from these systems on human health must be addressed.

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Evaluation of Bread Wheat (*Triticum aestivum L.)* Genotypes for Stripe Rust (*Puccinia striiformis f. sp. tritici*.) Resistance, Yield and Yield Attributes at Arsi High Lands, South Eastern Ethiopia

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Abstract:
The present study carried out with the objective to evaluate and identify stripe rust resistant bread wheat genotypes conducted using lattice design under natural epidemic conditions in 2021 main cropping season at Kulumsa and Meraro,South Eastern Ethiopia. Slow rusting resistance was assessed using both disease and yield and yield trait parameters. Highly significant(P<0.01) differences were noted among the 100 tested genotypes for most parameters noted above. Except genotype 231237(62.013q/ha),none of the rest tested genotypes sustained better disease reaction and grain yield than MR check Wane (61.012(q/ha).On the other hands, seven genotypes Kingbird (48.05qt/ha), 6883 (48.5qt/ha),235038 (50.21qt/ha), 231487 (49.99qt/ha), Huluka (48.47qt/ha), 20411 (44.49qt/ha, 226283(44.3qt/ha) over yielded MS check Dursa (43.88qt/ha .Genotypes with MR reaction and MS reaction and gave yield better than Dursa are recommended for yellow rust resistance breeding and yield improvement.

Keywords: Adult plant resistance, Evaluation, Bread Wheat, Stripe rust, Genotypes.

INTRODUCTION

Diseases are the main constraints for the low production and productivity of wheat in Ethiopia. Major wheat diseases are caused by both abiotic and biotic factors. Among abiotic constraints; low soil fertility and moisture stress are the principal wheat production limiting factors in Ethiopia (Hailu et al.,2012) .The major biotic factors that limit wheat production in Ethiopia include diseases, insect pests and weeds (Ayana, 2020).

Rusts including leaf rust (*P.triticina Eriks*),stem rust (*Puccinia graminis f.sp.tritici*) and yellow / stripe rust (*P.Striiformis West end f.sp.tritici*) are vital diseases reducing wheat productivity in Ethiopia (*Netsanet et al.,2014*) . Rust affects economically important plant species and usually appears as yellow, orange, red rust, brown or black powdery pustules on leaves, young shoots and fruits (*Perera et al.,2020*).

Yellow (stripe) rust that was first reported by Ciccarone (1947) is one of the major diseases of wheat in temperate regions as well as in the highlands of the tropics and subtropics including Ethiopia and it is considered as a low temperature disease. *Puccinia striiformisf.sp. tritici*. Westend: is a highly specialized obligate biotrophic fungus causing macro cyclic stripe (yellow) rust. Recently, it has been considered to be macro cyclic rust, after the identification of beriberi's species as an alternative host (Wang et al.,2009). New races virulent to Yr27+resistance gene and race Pst-16 recently affected most of commercial bread wheat cultivars including the popular varieties (Galama, Kubsa and Ogolcho) and caused 70 to 100% yield losses in the major wheat producing highland areas of Ethiopia (Strait et al.,2014).

Results of different experiments conducted for the control of wheat stripe rust around the world including Ethiopia revealed that increasing resistant cultivars still a preferred approach, because it is effective, easy to use, economical and environmentally friendly strategy (Bekele et al.,2002). Therefore, searching for resistance sources against wheat yellow rusts diseases is becoming crucial to sustain wheat production through growing disease resistant and high yielding cultivars and contributing to food security. Hence this study aimed with the objective to sustain wheat production through growing disease resistant and high yielding genotypes and contributing to food security.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Kulumsa and Meraro Kulumsa Agricultural research stations in Arsi zone, Oromiya Regional State, South Eastern part of Ethiopia during 2021 main cropping season. Kulumsa represents mid highlands (2200 m.a.s.l) and located at 39^{O} 09′11′′E l and 08^{O} 01′10′′N It receives mean annual rainfall of 820 mm with monthly mean minimum and maximum temperature of 10.5 and 22.8°C and also loam soil type is the dominant (Birhan, 2011). Meraro substation is located at 07°24' 27''N, 39°14 '56'' E and has an altitude of 2990 m.a.s.l.This location is a frost prone agro ecology representing the extreme highland. The minimum and maximum temperature is 5.7 and 18.1°C, respectively and it obtains 1196 mm average annual rainfall. The dominant soil type is clay soil (Nitosols) which is slightly acidic (Ph=5.0) (Birhan,2011). Both Kulumsa and Meraro are representing stripe rust hot spot areas as a result the disease pressure also increased with altitude increasing (Bekele et al.,2002).

Planting Materials

The total of 100 bread wheat genotypes consisting of 80 land race bread wheat accessions (collections), 20 commercial varieties including three checks varieties, Morocco (universal rust susceptible), Wane (MR) and Dursa (MS) varieties to yellow rust were used. Bread wheat land race accessions and commercial bread wheat cultivars used in this experiment was obtained from the Ethiopian Bio diversity Institute and Kulumsa agricultural research center respectively for their low to mid and mid to highland adaptability test to rust resistance and yield traits.

Experimental Design and Testing Procedures

The experiment was laid out in lattice design with two replications on seed-bed prepared by two rows using row makers adjusted at 20 cm spacing. Fertilizers (DAP and NPS) applied at planting with the recommended rate. Genotypes were planted manually with seed rates of 125 kg/ha in two rows 1m length and 0.4m width with 20cm spacing between rows and covered manually.

Spacing between sub blocks and two replications were 1m and 1.5m. To enhance the natural stripe rust epidemics and sufficient disease development and ensure uniform spread of inoculums, infector rows consisting of mixtures four susceptible bread wheat varieties (Morocco, Digalu, Ogolcho and Kubsa) planted bordering the plots and weeding was done manually three times.

Field Disease and Yield and Yield Component Assessment

Disease severity data were taken five times within ten days intervals on plot bases starting from the onset of rust. Severity and infection response were noted on each genotype per plot and co efficient of infection and area under disease progress curve and coefficient of infection were derived from the field data. Yield loss data traits taken interns of tillers, lodging, seed per spike, grain yield and thousand seed weight.

Analysis of Variance (ANOVA) and Mean Separation

Disease, yield and yield component epidemiological parameters were generated for each tested bread wheat genotypes and analysis of variance and mean separation were performed following the procedures of Gomez and Gomez (1984) and using SAS version 9.3 (SAS,2012) and Tukey test for mean separation (SAS,2002). Clustering of genotypes was performed by average linkage Euclidean distance using Minitab software version 17.

Correlation analysis was done for disease parameters namely terminal yellow rust severity, area under progress curve, coefficient of infection, head/spike infection and grain yield and yield attributes (thousand kernel weight, tillers, lodging, grain yield, seed per spike) using the general linear model procedure of SAS version 9.3 statistical software (SAS,2012) and Minitab software version 17,whereas principal component analysis carried out using the same software and grouped the genotypes by the clusters.

RESULT AND DISCUSSIONS

Terminal Wheat Yellow Rust Severity

Terminal/final rust severity signifies the collective result of all resistance factors during the progress of epidemics (Parlevliet and Van Ommeren,1975). According to Safavi (2012), genotypes falling into 1-30, 31-50% and above 50% severity classes possess high, moderate and low adult plant resistance level respectively. The current results indicated that there were high variations among genotypes in terms of disease development ranging from moderately resistant to highly susceptible genotypes which reveals resistant genotypes potentially reduce the disease severity while high disease severity on susceptible genotypes.In the present study 33 and 65 genotypes showed moderately and susceptible disease reaction respectively at Meraro site and 82 and 11 genotypes had moderately and susceptibility reaction at Kulumsa site respectively. Variety Wane and accession 231237 showed moderately resistant/MR with terminal rust severity ranging between 23% and 30% in variabily with test locations.

Average Coefficient of Infection

Average coefficient of infection (ACI) computed for tested genotypes from disease severities and host reactions. According to Singh et al., (2002), genotypes that show high (MR) and moderate (MS) level of final rust severity and ACI could have durable resistance, which can serve in resistance breeding as good parents. Genotypes with ACI values of 0-20, 21-40,41-100 are regarded as genotypes possessing high, moderate and low levels of adult plant resistance respectively (Ali et al.,2008). The present study result revealed that 4%, 41% and 55% of the tested bread wheat genotypes were in the category of moderately Resistant (MR), Moderately susceptible (MS) and highly susceptible (S) respectively as measured by ACI.

Area Under Disease Progress Curve

Genotypes with rAUDPC values up to 30% of the check, were grouped as genotypes having high/MR level of partial resistance. While, those having rAUDPC values up to 70% of the check were grouped as moderately resistance/MS and genotypes having above 70% of the check were grouped as susceptible/S genotypes (Ali et al.,2009). In the present study, 19 genotypes with MS (231257, 231609, 231215, 5774, 234250, 231632 ,235040, Lemmu, 222240, 231627, 6930, 6883, Dursa), MS/S (Boru, Balcha), MS/MR (234258), MR (231237, Wane) and S reactions (Kubsa) have lowered AUDPC values over Morocco by more than 60%.

Head Infection

Test genotypes differed significantly (P<0.01) and compared using LSD (least significance difference) and MSD (minimum significant difference). Response of genotypes to head infection in terms of 0-5 rating scale and percentage spike infection is summarized in figure 1 below.

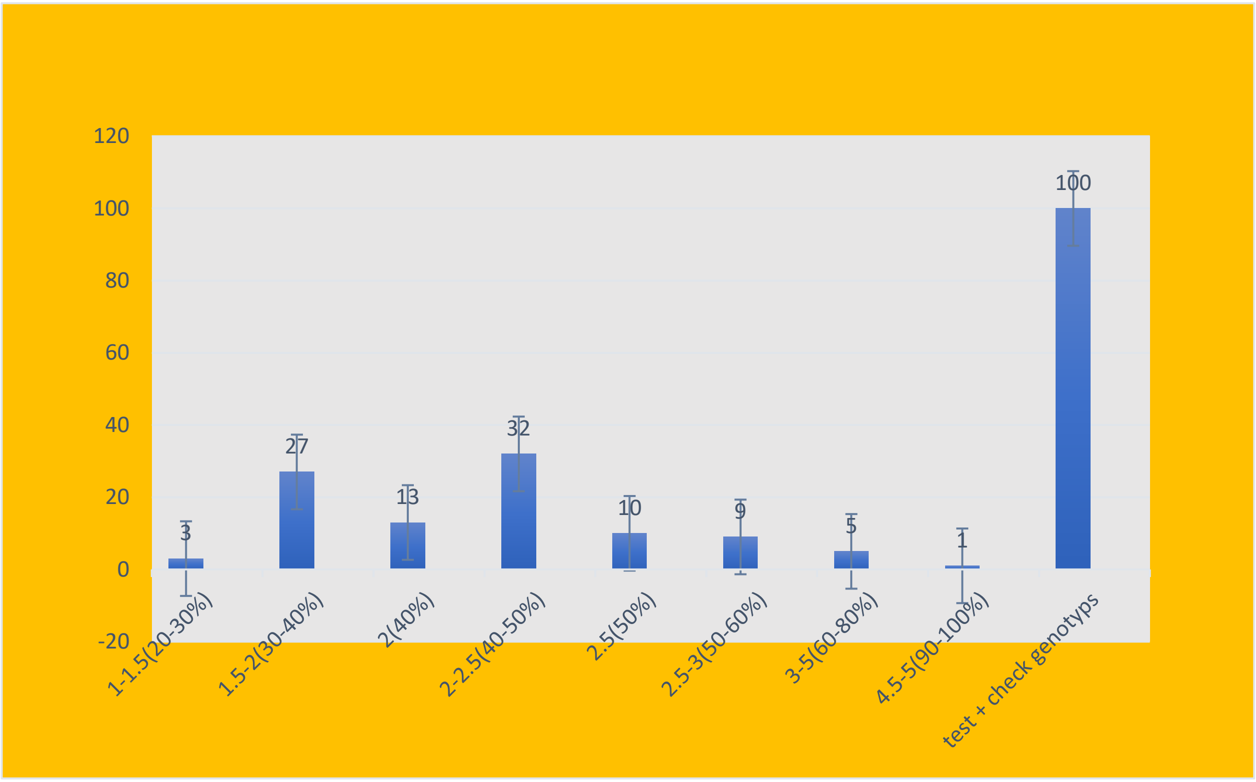

Figure 1: Response of 100 bread wheat genotypes to head infection frequency in terms of 0-5 rating scale and percentage spike infection, Meraro and Kulumsa sites average infection, main season,2021.

Analysis of Variance (ANOVA)

Combined ANOVA of agronomic and disease parameters showed significant variation among 100 evaluated bread wheat genotypes. The results showed AUDPC and all agronomic parameters were significantly different among tested genotypes. The analysis of variance showed highly significance difference at (P<0.01) except thousand seed weight and Grain yield per Quantals (GYQPH), this may be happened due to the mobility character of most of their genetic resource for disease or stress response than yield response (table1).

Table 1. Combined mean squares for seed yield, yield component and disease parameters for tested 100 wheat genotypes across two test locations, Meraro and Kulumsa,2021.

Traits	Mean Squares					
	SITE (df=1)	REP (df=1)	BLK(REP), df=18	Genotypes, df=99	SITE*Entry, df=99	Error, df=18
AUDPC	34151751.6**	3770781.42**	249361.98**	265225.05**	59816.95ns	94165.60
FRS	34399.12**	3950.12**	379.58**	334.73**	115.68ns	143.71
CI	49062.25**	6099.61**	707.25**	651.46**	131.77ns	257.83
HI	38533.69**	5520.49**	391.48**	395.76**	95.71ns	163.26
Tillers	597.80**	0.72 ns	1.40 ns	2.90**	1.40*	1.01
Lodged	564.06**	37.82*	10.98*	18.16**	3.38ns	5.83
SL	201.64**	0.49 ns	14.51**	29.02**	1.42ns	4.53
SPS	19030.20**	1.32ns	21.07*	40.05**	24.94**	12.21
TKW	539.47**	464.98**	63.01Ns	66.72ns	55.54ns	56.03
GYQPH	25115.75**	1312.72**	152.12ns	219.18**	82.13Ns	102.23

Key:AUDPC=Average Disease Progress Curve, CI=Coefficient of Infection, GQPH=Grain Yield Quantals per Hectare, HI=Head infections, MSE=Mean Squares of Error, MSB=Mean Squares of Blocks, MSG=Mean Square of Genotypes, ns=Non significance. SPS=Seed per Spike, SL=Spike Length, TRS=Terminal Rust Severity%, TKW = Thousand Kernel Weight. *= Significant at P < 0.05 and **= significant at P< 0.01, ns(non-significant) at P>0.05.

Grain Yield and Thousand Kernel Weight

As demonstrated in figure below the yield can increase as resistance increasing from susceptibility (Morocco) to moderately resistance (Wane). The yield increment was higher at Kulumsa than at Meraro test locations, where the disease pressure registered reciprocal (figure 2). According to several authors including Krupinsky et al., (2002), yield differences can be associated with differences in the agro ecology and the level of genotypes tolerance to stresses.

Figure 2: Compared analysis for the high yielder genotype 231237 with MR (wane), MS(Dursa) and S(Morocco) checks.

Correlation of Disease, Grain Yield, Yield and Yield Components

The results showed that correlation among most of the yield and yield components are positive and significant. The disease parameter, AUDPC, was correlated with grain yield and yield components negatively (table 2). Therefore, apparently, resistant genotypes identified are reducing the disease pressure and increasing yield used as sources of stripe rust resistance breeding and high yielding and responding to agronomic practices.

Table 2. Pearson linear correlation coefficient among tripe rust disease parameters, yield and yield components,data collected from Kulumsa and Meraro sites and from 100 bread wheat genotypes,main season.2021.

	AUDPC	TRS	CI	HI	Lodging	Spike L	SeedPspike	TKW	GYQPH
TRS	0.863**								
CI	0.936**	0.909**							
HI	0.927**	0.807**	0.913**						
Tillers	-0.606* *	-0.478**	-0.574	-0.637**					
Lodging	-0.045ns	-0.004ns	-0.070ns	-0.068ns	0.021ns				
Spike L	-0.270**	-0.222*	-0.279**	-0.199*	0.122ns	0.341**			
SeedPspike	-0.423**	0.369**	-0.448**	-0.453**	0.542**	0.178ns	0.173ns		
TKW	-0.132ns	-0.051ns	-0.081ns	-0.203*	0.283*	-0.141ns	-0.216*	0.321**	
GYQPH	-0.171n	-0.137ns	-0.136ns	-0.145ns	0.106ns	-0.242*	-0. 343	** 0.069ns	0.313**

Key: I=Coefficient of Infection, GYQPH=Grain Yield Quantals per Hectare, HI=Head/Spike Infection, SPS=Seed per Spike, SL=Spike Length, TRS=Terminal Rust Severity, TKW=Thousand Kernel Weight. NB. *= Significant at P < 0.05, **= significant at P< 0.01, ns (non-significant) at P>0.05.

Cluster Analysis

In the present study 100 genotypes were grouped into five clusters using average linkage Euclidean distance using MINITAB17 software (MINITAB,2003). Among the five clusters maximum inter cluster distance was found between cluster 1 and cluster 3 indicating possibility of inter crossing the genotype of the two clusters. While highest intra clusters some of square (1037.68) was recorded in cluster 1 which consists of 92 genotypes.

The cluster analysis grouped the 97 test genotypes and three check varieties into five distinct categories based on their disease and yield and yield traits obtained at Meraro and Kulumsa. Members within a single cluster were considered as similar or as having more close relationships with each other than those in distant clusters (table 3).

Table 3. Clusters of 100 Bread wheat genotypes in to different diversity classes.

			Cluster-1				Cluster2	Cluster3	Cluster4	Cluster5
G-1	G-17	G-32	G-47	G-62	G-77	G-96	G-4	G-85	G-98	G-100
G-2	G-18	G-33	G-48	G-63	G-78	G-99	G-97	G-90		
G-3	G-19	G-34	G-49	G-64	G-79			G-91		
G-5	G-20	G-35	G-50	G-65	G-80			G-93		
G-6	G-21	G-36	G-51	G-66	G-81					
G-7	G-22	G-37	G-52	G-67	G-82					
G-8	G-23	G-38	G-53	G-68	G-83					
G-9	G-24	G-39	G-54	G-69	G-84					

G-10	G-25	G-40	G-55	G-70	G-86					
G-11	G-26	G-41	G-56	G-71	G-87					
G-12	G-27	G-42	G-57	G-72	G-88					
G-12	G-27	G-42	G-57	G-72	G-88					
G-13	G-28	G-43	G-58	G-73	G-89					
G-14	G-29	G-44	G-59	G-74	G-92					
G-15	G-30	G-45	G-60	G-75	G-94					
G-16	G-31	G-46	G-61	G-76	G-95					

Key; G=Genotypes.

Cluster1:
It consisted of 92 genotypes. Among these clusters the genotype/accession, 231237 followed by Dursa (Moderately susceptible/MS check) is high yielder in seed per spike and TKW as compared to wane (Moderately Resistant check) and hence recommended for yellow rust resistance and high grain yielding variety development.

Cluster2:
It consisted of 2 genotypes with highly susceptible check (Morocco) and moderately resistance (214312) with low (16.17) to an intermediate (31.42) yield per hectare and yellow rust resistance, respectively.

Cluster3:
It consisted of 4 genotypes collected from Oromia and Amhara regional states. 214466, 226893,226898 and 231484 with an indeterminate yield of 33.11qt/ha,41.69qt/ha, 39.25qt/ha and 38.46qt/ exhibiting an intermediate resistant to yellow rust disease.

Cluster4:
It had one genotype (Ogolcho) having S to MS yellow rust reactions at Meraro and Kulumsa respectively. Exhibiting an intermediate, seed yield Quintals per hectare, number of seeds per spike, spike length,TKW and resistant to yellow rust disease.

Cluster5:
This cluster consists 1 genotype Wane (MR check) that is exhibiting high yield per hectare,spike length, seed per spike of 61.012 quintals,13.27cm,12.59 seeds, respectively and characterized by moderately resistance reaction to yellow rust.

CONCLUSION

In this study among the one hundred tested bread wheat genotypes,the Moderately resistant (MR) and moderately susceptible (MS) genetic materials identified can be used for wheat yellow rust resistance breeding,of them,genotypes Kingbird(48.05qt/ha) ,6883(48.5qt/ha),235038 (50.21qt/ha), 231487 (49.99qt /ha), Huluka(48.47qt/ha),20411 (44.49qt/ha,226283 (44.3qt/ha) were tolerant and over yielded MS check Dursa (43.88qt/ha) despite they had susceptible reaction to disease. Thus,I recommend them for further in yellow rust resistance breeding and improving yield.

On the other hand, genotype 231237 is recommended for having low terminal severity MR reaction and higher yield invariably with MR test check (Wane) across locations and thus can be used as a source germplasm to diversify the genetic base of wheat and improve durability of resistance in Ethiopia. However, "rust never sleeps", famously quoted by Norman Borlaug still initiates additional investigations of resistant genes contained in the candidate genotype, which can only be confirmed by molecular analysis. Therefore, evaluation of the wheat germplasm including land races in the field and green house, genotyping using known markers, investigating their physio chemical quality parameters to confirm the resistant Yr. gene carried with germplasm are all crucial points to be taken into consideration in the future yellow rust resistance breeding.

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