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EFFECTS OF SOIL HEATING ON SOIL PROPERTIES, LEAF AREA DEVELOPMENT, DRY MATTER PRODUCTION AND PARTITIONING AND GROWTH OF MAIZE *(Zea mays*) ON AN ALFISOL IN MAKURDI, SOUTHERN GUINEA SAVANNA ZONE

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ABSTRACT

The effect of prescribed heating on soil properties of a sandy loam soil was studied. Its effects and fertilizer application on leaf area development, growth, and efficiency of dry matter partitioning of maize was also examined. The treatments were a combination of 4 levels of heated soils, 27^{o}C, 100^{o}C, 200^{o}C and 300^{o}C and two fertilizer levels, FO (control) and F1 (300 kg/ha NPK fertilizer). Plant height and leaf area were taken at 21, 42 and 63 days after planting (DAP). Biomass harvests were collected at 21 and 42 days after planting to examine effects of soil heating and fertilization on shoot, stem, leaves and roots dry matter yield and partitioning. The results of the experiments revealed that heating between 27^{o}C to 200^{o}C decreased soil pH, organic carbon, total N, Ca, Mg, Na, K and CEC and increased NH^{+}_{4}-N and Fe. Heating beyond 200^{o}C decreases NH^{+}_{4}-N, Zn and Fe. The main beneficial effect of heating was attributed to increased available NH^{+}_{4}-N at lower degree of heating. The results of the study further showed that plants grown on soil heated at 200^{0c} and fertilized had higher plant height and leaf area. The heated soils were more efficient in allocating dry matter at latter periods to roots and stem. Control bush burning at temperatures less than 300^{o}C could be beneficial for plant growth and efficient allocation of dry matter.

Keywords: *Zea mays*, leaf area, plant height, dry matter.

INTRODUCTION

In the southern Guinea savanna zone of Nigeria, as in other parts of the tropics, burning has been regarded as the fastest, cheapest, and most convenient means for the removal of plant residue and other debris from the land in readiness for seed bed preparation for a new cropping session.

In Australia, New Zealand, and the west and southern United States, burning is considered as a major management tool (Ojeniyi *et al*., 2005). In Australia, fire is particularly used for waste disposal and conversion of forest composition from indigenous to exotic species.

Bush burning affects physical, chemical and biological fertility of the soil. Knight (1996), Kang and Sajjapongse (1980), Iwuafor *et al*. (2000) all reported decreases in CEC, organic carbon, total Nitrogen and increase in exchangeable K, Mg, Ca, available P, pH, NH^{+} 4-N as a result of soil heating. These changes are bound to affect the growth of crops. A comprehensive review of burning/fire and ecosystem has been published (Raison, 1979). These changes in soil properties as a result of burning are bound to affect the growth of crop. The crop growth according to Cromer (1970) is enhanced by mild heating because of immediate increase in soil productivity while the situation is temporally opposite with severe heating. Laude lout (1964) earlier reported wide range of temperature due to burning; he attributed that to the differences in the amount and type of residue burn and the length. There is however, little information on the effect of soil heating on soil properties and crop performance in the Southern Guinea Savanna. The objective of this experiment was to compare changes in soil properties, growth and dry matter yield and partitioning of a maize variety grown on an Alfisol under different degrees of heating. The basic hypothesis was that increase in degree of soil heating would bring about changes in soil properties, increase plant height, leaf area and would therefore increase the efficiency in dry matter production and partitioning.

MATERIALS AND METHODS

The study was conducted at the University of Agriculture, Makurdi. The soil used in the study was a sandy loam (Table1). The soil was collected from the top 15 cm of the profile. The sample was air dried and passed through a 2mm mesh. Sub samples were heated at temperatures of 100^{0}C, 200^{0}Cand 300^{0}C for six hours in a muffle furnace. Batches of soils were heated until sufficient quantities were obtained for a pot experiment. The treatments were combinations of heated soils, 27^{0c} (control), 100^{0}C, 200^{0}C and 300^{0}C and two fertilizer levels F0 (without fertilizer) and F1 (with 300 kg/ha NKP fertilizer). The 27^{o}C temperature was arrived at by leaving the sample unheated. The treatments were arranged in a randomized complete block design and replicated four times. Five (5) kg of each soil was weighed into a plastic pot with drainage holes at the base.

Four maize seeds (DMSRW) were sown per pot and latter thinned to two plants one week after planting. The soils were maintained with water daily at field capacity. Leaf area and plant heights were taken at 21, 42 and 63 Days after planting (DAP). The leaf area was estimates by the formular A = 0.75 x length x width. Biomass measurements were collected at 21, 42 and 63

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DAP, one plant was carefully removed from each pot and the plant was separated into leaves (L), stem (S) and roots (R). The samples were then oven dried for 2 days at 60^{0c} prior to dry matter determinations. Dry matter partitioning ratios (L/TOT, S/TOT, L+S/TOT and R/TOT) were calculated by dividing the dry weight of a given plant component or set of plant components by the total dry weights per plant (TOT). Data for leaf area, dry weights, and partitioning ratios at each sampling were analyzed as a separate experiment. Analysis of variance and Duncan's multiple range mean separation test were used to evaluate significant differences in plant height, leaf area dry matter production and partitioning.

RESULTS AND DISCUSSIONS

Soil properties

The effect of prescribed heating on soil properties is presented in Table1. Heating the soil up to 300^oC increased sand fraction and decreased the clay and silt fractions. At higher temperatures, there was complete fusion of clay and silt fractions to the size of sand fractions, hence the dominance of sand fractions. Iwuafor *et al*. (2000) obtained similar results when they heated soil samples up to 400^oC.

Heating the soil up to 200^oC decreased soil pH while organic carbon and total Nitrogen decreased linearly as an increase in the degree of heating. The decrease in soil pH may be attributed to the oxidation - reduction reaction and the release of Al and Fe ions from the organic matter in the process of decomposition.

The decreased of organic carbon with increased degree of heating could be due to oxidation (Rendel, 1981). Most organic and even inorganic colloids are altered by heating soil at higher temperatures (Humphrey *et al*., 1969). Hosking (1938) earlier reported that heating soil for six hours at less than 100^oC could lead to small losses of soil organic components while heating at higher degree could remove 99% of the organic carbon.

The decreased in the total Nitrogen content of soil with increasing degree of heating was related to the decrease in organic Nitrogen contained in organic Matter (Knight, 1996). The Nitrogen lost is usually in form of ammonia and other related Nitrogen gases. Light burning, however, may increase organic Matter and total N levels in the soil profile (Wells, 1971) probably as a result of addition of partly combusted materials (smith, 1970) or increased soil productivity. Wehrman and Johannes (1965) reported that severe heating reduce soil organic Nitrogen and increase soil inorganic Nitrogen. This probably explains why plant response quicker on burn sites.

The increase in ammonium - Nitrogen with increased degree of heating up to 200^{oc} could be due to the production of ammonia as a result of break down of organic matter. High levels accumulation of NH +4 N in heated soil have been reported and much of its production is immediately (Russell *et al.*, 1974).

Heating the soil up to 200^oC increased Mn, Zn and Fe while Cu decreased. Available phosphorus increased linearly with the degree of heating. Heating the soil up to 200^{oc} increased available phosphorus by over 375%. Organically bound phosphate, Fe and Zn might have been released after heating thereby accounting for the increase in available Phosphorus, Fe and Zn (Kitur and Frye, 1983).

Exchangeable K decreased with all heating degrees. Iwuafor *et al*. (2000) however reported increased in K at all soil eating temperatures. Heating the soil up to 200^oC decreased Ca content, and thereafter increased throughout the degree of heating, while Mg decreased with heating, after 200^oC. CEC on the other hand decreased with increased degree of heating. The effect of heating on Na was however, less obvious. Knight, (1996) also reported the same on CEC and Na; his reports however vary with this findings on Ca and mg.

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Table-1. Physical and chemical properties of the soil before and after heating.

Parameters	**Amount in untreated and treated soils**			
	27^0C	100^0C	200^0C	300^0C
Sand (%)	72	760	740	760
Clay (%)	12	100	120	100
Silt (%)	16	140	140	140
Total N (%)	0.103	0.105	0.070	0.070
NH^+ 4-N (mg/kg)	13.95	28.05	154.75	37.85
Organic carbon (%)	1.66	1.44	1.16	0.75
pH (H_20)	6.50	6.60	6.50	6.70
0.0/M CaC/2	5.90	6.30	6.30	6.50
Available P (ppm)	7.00	15.75	55.13	70.00
Ca (Cm01/kg)	8.60	7.00	7.00	7.40
Mg (Cm0l/kg)	1.69	1.99	1.74	1.54
Na (Cm0l/kg)	0.22	0.53	0.46	0.47
K (Cm0l/kg)	0.87	1.59	1.43	1.59
H^+ Al (Cm0l/kg)	0.40	0.20	0.20	0.10
Cu (Cm0l/kg)	3.90	3.50	2.10	1.70
Mn (Cm0l/kg)	57.10	19.50	20.50	12.50
Fe (Cm0l/kg)	1440.50	1600.50	1720.50	420.50
CEC (Cm0l/kg)	14.60	13.80	12.80	15.10

Leaf area development

The effect of soil heating and fertilizer application on leaf area development is presented in Table-2. Leaf area development was significantly affected by the degrees of heating and fertilizer application. At 21 DAP, Leaf area development increased as the heating increases up to 200^0C beyond which there were drops. Addition of fertilizer further increased the development of leaf area.

Leaf area development at 42 DAP and 63 DAP were all significant. The trends were however, the same as observed at 21 DAP. At 200^0C increases in leaf area development over the control with fertilizer application were 138%, 156.5% and 138% for 21DAP, 42 DAP and 63 DAP respectively. This showed that leaf area development increased with days after planting and eventually begins to decline. The increase in leaf area development of maize plant observed with soil heating up to 200^0C may be attributed to increases in available nutrients (N, P, K, Ca Mg, Zn, Fe and Mn). Sonneveld and Voogt (1973) observed that mild heating also refers to as sterilization results in an immediate increase in soil productivity, while severe heating or steaming render the soil temporarily unsuitable for plant growth.

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Table-2. Effect of soil heating and fertilizer application on leaf area development.

Treatments		**Leaf area** (cm^2)		
Heating (^0C)	**Fertilizer levels**	**21 DAP**	**42 DAP**	**63 DAP**
27	F0	35.373	131.2506	159.9475
27	F1	39.375	135.2494	163.9475
100	F0	45.615	203.5481	257.6650
100	F1	49.615	207.5469	260.6650
200	F0	89.763	342.9706	386.2200
200	F1	93.763	346.9694	390.2075
300	F0	72.180	239.2181	323.215
300	F1	76.180	243.2169	327.2175
LSD (0.05)	-	0.2826	0.03622	0.02468
Mean	-	62.733	231.2463	283.6353
SE ±	-	0.1359	0.01741	0.01187
CV %	-	0.3	0.0	0.2

DAP = Days after Planting

Plant height and dry matter yield

The effect of soil heating and fertilizer application on plant height and dry matter yield are presented in Tables 3 and 4 respectively. Plant heights were significantly increased with soil heating and fertilizer application throughout the sampling periods (21 DAP, 42 DAP, 63 DAP). Plants grown in pots with soil heated to 200^{0}C with fertilizer were significantly taller than plants grown in soils heated at lower and higher temperature ranges.

Total dry matter yield, and dry matter yields of shoots, leaves, stem and roots increasing in soil heating temperature up to 200^{0}C with fertilizer beyond which there were drops (Tables 4 and 5). The increase were significant throughout the sampling periods (21 DAP, 42 DAP). Plants grown on soil heated at 200^{0}C accumulated more total dry matter in all components than those grown in soils heated at other temperatures. It was observed that the dry matter yield increased with plant age. The increase in dry matter yield and plant height of the maize observed with soil heating up to 200^{0}C may be attributed to increases in available nutrients.

Murkerjee (1954) reported higher weights of rice and barley in experiments where the soil was also heated to 200^{0}C. Iwuafor *et al*. (2000) also reported that dry matter yield and plant height of maize increased as a result of heating Alfisols from the northern Nigeria up to 200^{0}C. They attributed this to the increase in extractable nutrients due to heating. They also explained that at higher temperatures there was complete destruction of organic matter and fusion of the clay fractions to the size of sand fractions which resulted in reduction of the soil CEC. The low nutrient content coupled with low nutrient capacity and the low water retention capacity may have resulted in the low dry matter yield and plant height (Kang and Sajjapongse, 1980).

Table-3. Effects of soil heating and fertilizer application on plant height.

Treatments		**Plant height** (cm)		
Degree of heating (^{0}C)	**Fertilizer levels**	**21 DAP**	**42 DAP**	**63 DAP**
27	F0	10.2525	62.3650	65.06
27	F1	14.2525	66.3650	69.060
100	F0	9.7525	63.0150	72.532
100	F1	13.7525	67.0125	76.532
200	F0	16.2525	86.3150	93.650
200	F1	20.2525	90.3150	97.650
300	F0	11.6325	67.6650	81.045
300	F1	15.6325	71.6650	85.045
LSD (0.05)	-	0.2129	0.01916	0.0955
Mean	-	13.9725	71.8397	80.072
SE ±	-	0.01024	0.00921	0.0459
CV %	-	0.1	0.0	0.1

DAP: Days after planting

Table-4(a). Effects of soil heating and fertilizer application on dry matter yield (21 DAP).

Treatments			**Dry matter yield** (g/s)			
Heating (^{0}C)	**Fertilizer levels**	**Total**	**Shoot**	**Leaves**	**Stem**	**Roots**
27	F0	5.00	3.200	2.70	0.500	1.800
27	F1	9.000	6.200	4.20	2.000	2.800
100	F0	3.525	2.100	1.80	0.300	1.400
100	F1	7.525	5.100	3.30	1.800	2.400
200	F0	11.025	7.300	5.20	2.100	3.700
200	F1	11.025	10.300	6.70	3.600	4.700
300	F0	7.525	5.500	3.80	1.700	2.000
300	F1	11.525	8.500	5.30	3.200	3.000
LSD (0.05)	-	0.2926	0.6482	0.841	0.7898	0.7793
Mean	-	8.769	6.025	4.13	1.900	2.725
SE ±	-	0.1407	0.3117	0.404	0.3798	0.3747
CV %	-	2.3	7.3	13.9	28.3	19.4

DAP: Days after planting

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Table-4(b). Effects of soil heating and fertilizer application on dry matter yield. (42 DAP).

Treatments			**Dry matter yield** (g/stand)			
Heating (^{0}C)	**Fertilizer levels**	**Total**	**Shoot**	**Leaves**	**Stem**	**Roots**
27	F0	24.00	12.95	7.64	5.31	11.050
27	F1	30.50	15.95	9.14	6.81	12.050
100	F0	20.75	11.53	5.73	5.80	9.200
100	F1	24.73	13.53	6.73	6.80	11.200
200	F0	40.38	23.88	11.81	12.07	16.500
200	F1	44.38	25.88	12.81	13.07	18.500
300	F0	36.78	16.36	8.20	8.16	20.470
300	F1	40.83	18.36	9.20	9.16	22.470
LSD (0.05)	-	2.818	0.963	1.273	1.253	0.8022
Mean	-	32.75	17.30	8.91	8.40	15.180
SE ±	-	1.355	0.463	0.612	0.603	0.3858
CV %	-	5.8	3.8	9.7	10.1	3.6

DAP = Days after planting

Dry matter partitioning

Pattern of dry matter partitioning, total shoot, (leaves + stem/total), leaves (leaves/total), stem (stem/total) and roots (roots/total) are presented in Table-5. Partitioning to shoot, stem, leaves and roots were all significant at 21 DAP and 42 DAP. Partitioning to shoot, stem and roots increased and leaves decreased with age. These contrasting patterns of dry matter accumulation to leaves and stem and roots indicate a shift in sink capacities with plant age.

As plant aged, leaves had a limited sink capacity while stem and roots were the dominant competitor for assimilates. This shift in sink capacities occurred in both the heated and unheated soils. But the fact that the stem/total and roots/total in the heated soils and fertilized increased sharply as plant development proceeded suggest that the sink capacities of stem and roots were enhanced by the heating and fertilization.

It was observed that the heated soils were more efficient in allocating dry matter at latter periods to roots, this may be due to production of a toxic substances due to heating which can be latter reached from the soil by water or gradually detoxified by microorganism (Rovira and Bowen, 1966). Renbuss, (1968) observed that roots growth may be impaired for a time in heated soils, but later may become superior to that in unheated soils.

Table-5(a). Dry matter partitioning ratio as affected by soil heating and fertilizer application.

Treatments		**Shoot ratio**		**Leaves ratio**	
Heating (^{0}C)	**Fertilizer levels**	**21 DAP**	**42 DAP**	**21 DAP**	**21 DAP**
27	F0	0.54	0.54	0.54	0.32
27	F1	0.47	0.57	0.47	0.33
100	F0	0.51	0.56	0.51	0.28
100	F1	0.44	0.55	0.44	0.27
200	F0	0.47	0.59	0.47	0.29
200	F1	0.45	0.58	0.45	0.29
300	F0	0.51	0.44	0.51	0.22
300	F1	0.46	0.45	0.46	0.23
LSD (0.05)	-	0.03	0.04	0.03	0.02

DAP = Days after planting

Table-5(b). Dry matter partitioning ratio as affected by soil heating and fertilizer application.

Treatments		Stem ratio		Root ratio	
Heating (^{0}C)	Fertilizer levels	21 DAP	42 DAP	21 DAP	42 DAP
27	F0	0.10	0.22	0.36	0.4850
27	F1	0.22	0.24	0.31	0.4300
100	F0	0.09	0.28	0.40	0.4400
100	F1	0.24	0.28	0.32	0.4500
200	F0	0.19	0.30	0.34	0.4100
200	F1	0.24	0.30	0.31	0.4200
300	F0	0.23	0.22	0.27	0.5600
300	F1	0.28	0.22	0.26	0.5500
LSD (0.05)	-	0.02	0.02	0.03	0.04

DAP = Days after planting

CONCLUSIONS

The response of a sandy loam and maize crop under varying degree of soil heating and fertilizer application in the southern guinea savanna zone was studied. Heating at temperatures greater than 200^{0}C results in unfavorable soil conditions and drastic reduction in plant growth and dry matter yield. Fertilizer application significantly increased dry matter yield and plant height. All the selected maize parameters (Plant height, leaf area, dry matter production and partitioning were affected by soil heating and fertilizer application. It is suggested that control bush burning at temperature less than 300^{0}C should be adopted for efficient plant growth, leaf area and efficient dry matter allocation to roots and stem.

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