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Effect of plant biomass and their incorporation depth on organic wheat production in Kenya

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Abstract:
Intensive agricultural technologies introduced in Africa some six decades ago paved the way for extensive land clearing and destruction of organic materials, development of high yielding crop varieties under monoculture and replacement of landraces. Simultaneously, pesticides and antibiotics for use in agricultural pest and disease control were being developed and soon the face of agriculture was transformed by what was termed the Green Revolution. However, the apparent success accruing from such heavy investment was short-lived since the system would easily succumb to soil erosion, reduced soil organic matter, environmental pollution and pest and disease outbreaks. The inevitable result is the inability of land to sustain food productivity and worsening poverty. In response to these dangers, organic agriculture is considered a viable approach which meets the critical need for food security, food safety, as well as human and environmental health. The use of naturally occurring and locally available farm inputs such are plant materials, animal manures and mineral nutrient rich rock ores such as rock phosphates as plant nutrient sources are instrumental in refurbishing soil fertility in a sustainable and economical way. In this experiment, green manures derived from Tithonia diversifolia*,* Dolichos lablab *and* Tephrosia vogelli *were evaluated for their effect on the performance of organically grown wheat. These materials were incorporated at different soil depths namely; 0 cm (mulch), 15 cm and 30 cm deep. Rock phosphate was used as a source of phosphorus and wheat was planted 2 weeks after incorporation. Significant yield increase (15% higher than the untreated control) was observed in the* Tithonia *treatment. This was attributed to the high nutrient concentrations and the quick release of these nutrients in the tissues of* Tithonia*. Shallow applications of the plant materials also gave better responses than deep application. Apparently, shallow applications are appropriate for shallow rotted crops like wheat. It was concluded that locally available plant material of high nutrient concentrations which decompose easily to release its nutrients can complement other soil management packages for organic crops in Kenya.*

Introduction:

Practices such as burning or removal of crop residues from crop fields leads to a decline in soil organic matter which in turn reduces the lands ability to hold water, cations, and to support soil micro-flora and a sustainable crop yield. There was loss of traditional knowledge on use of ethno-botany for disease and pest control and an increase in pests, diseases and weeds incidences coupled with a rise in environmental pollution and an increase in pesticide related human diseases. The intensive agricultural systems based on high external inputs are not sustainable and threatens food security in Kenya, particularly at smallholder level.

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The weaknesses of the Green Revolution are pronounced in tropical environments like Kenya where the warm climate favours the rapid decomposition and loss of soil organic matter. In traditional agriculture, arable land could be left fallow for some years to allow soil to acquire self-rejuvenation, but increased population pressure leads to shorter fallow periods, which are not sufficient to restore the soil nutrient pools and soil organic matter levels sufficient to support economic crop yields. In Kenya, 80% of the farmers are classified as small-scale who cannot afford high input investments.

There is therefore a need to examine crop production systems that could promote sustainable crop production in Kenya. The organic system favours the use of renewable resources and emphasizes the use of techniques that integrate natural processes such as nutrient cycling, biological nitrogen fixation and soil regeneration.

This research provides a case study of how organic farming can sustain the yields of stable food crops in Kenya. The trial was designed with a purpose of identifying appropriate cropping systems for long-term restoration of natural soil productivity. Green manures derived from high-nutrient legumes (*Dolichos lablab* and *Tephrosia vogelii*) and a non-legume (*Tithonia diversifolia*) species were either used as mulch or incorporated into the soil at various depths to understand the most appropriate biomass management strategy that will lead to quick release of nutrients. The effects of these organic farming strategies on yield of wheat are reported.

Methods:

The experiment was carried out at Egerton University, Nakuru district in Rift Valley province of Kenya for a period of five months beginning April to September, 2005. It involved the application of green manures from three species, namely: *Tithonia* (*Tithonia diversifolia), Lablab* (*Dolichos lablab*) and *Tephrosia* (*Tephrosia vogelli*). The material was applied at a uniform rate of 2 tons/ha except for the control plot which did not receive such materials. The plant material from each species was applied using three different methods, namely: mulch, incorporation into the soil at 15 cm and at 30 cm depth. This gave rise to ten treatments including the control. The experiment was laid out in a randomized complete block design (RCBD) with 4 replication on 40 plots. The plot size measured 3 m x 2.5 m. Two weeks after application of the plant material, rock phosphate at a rate of 290 kg/ha (46 kg P_{2O5}/ha) was broadcasted uniformly in all the 40 plots. Fifteen planting furrows that are 20 cm apart were then made in each plot to a depth of about 3 cm. Wheat seeds were then sown uniformly along the rows.

Data taken included the plant height at 100% flowering, spike length at grain filling stage and grain yield at harvesting. All data was analyzed statistically using analysis of variance (ANOVA). Differences between treatments were analyzed by Duncans Multiple Range test.

Results:

Effect of organic green manures on wheat

The different plant materials incorporated into the soil had little effect on the total height and spike length of the wheat crop, but significant ($P<0.05$) differences were observed in grain yield. *Tithonia* was more superior in influencing the grain yield followed by Tephrosia, Dolichos and the control in that order (Tab 1, Fig. 1). The *Tithonia* treatment gave an average wheat grain yield of 3905 kg/ha (15% higher than the control).

Tab. 1: Effect of organic plant materials on yield and yield components of wheat.

Biomass	***Average plant height at maturity (cm)***	***Average Spike length at maturity (cm)***	***Average wheat yield (Kg/ha)***
Dolichos lablab	88.9ns	8.4ns	3680ns
Tithonia diversifolia	87.5ns	8.3ns	3905*
Tephrosia vogelii	85.7ns	8.5ns	3822ns
Control (no application)	87.5ns	8.3ns	3297ns
Mean			

* significantly different at $P<0.05$, ns = not significantly different at $P<0.05$.

Effect of incorporation depth

The mulching treatment showed significantly (P<0.05) higher figures in all the parameters measured. Organic matter incorporation at 15 cm depth also increased yields significantly (Tab. 2, Fig. 2).

Tab. 2: Effect of biomass management on yield and yield components of wheat.

Incorporation depth (cm)	**Average plant height at maturity (cm)**	**Average Spike length at maturity (cm)**	**Average wheat yield (kg/ha)**
Incorporated at 15 cm	85.16ns	8.36ns	3809*
Incorporated at 30 cm	86.59ns	8.35ns	3772ns
Surface mulch	90.31*	8.48*	3806*
Control (no application)	87.41ns	8.31ns	3297ns
Mean			

* significantly different at P<0.05 , ns = not significantly different at P<0.05.

Discussion:

Plant residues as organic fertilizers

Different plant materials that are potential fertilizer sources to crops have different nutrient concentrations and have variable rates of decomposition and release of plant nutrients. In this experiment, *Tithonia diversifolia* increased grain yield significantly when compared to other biomass used in the experiment. However, all types of biomass were better than the control. The observation could be attributed to the higher nutrient concentrations and quick release in *Tithonia* already reported in other studies. In another experiment conducted in Maseno district of Western Kenya, *Tithonia* produced a total dry matter biomass of 11.8 t/ha during the six month growth period. The nutrient concentrations in the leaves were 30g/kg nitrogen (N), 1.8 g/kg phosphorus (P), 46 g/kg potassium (K), 19.1 g/kg calcium (Ca) and 3.7 g/kg magnesium (Mg). The shrub therefore had high concentrations of N, K and Ca but low in P and Mg (RUTUNGA et al. 1999). In the same experiment, *Tephrosia* accumulated 9.5 t/ha. Nutrient concentration in the leaves of Tephrosia leaves after the six month period were 30.5 g/kg N, 1.2 g/kg P, 15.7 g/kg K, 13.0 g/kg Ca and 4.7 g/kg Mg. The above ground biomass for the two shrubs accumulated higher amounts of N, K, Ca and Mg than the natural fallow and maize (RUTUNGA et al. 1999). Though *Tithonia* is a non-legume its ability to accumulate N is as high as that of Tephrosia, a N fixing legume. Additionally, it accumulates more P, K and Ca than *Tephrosia*.

The positive effects of *Tithonia* could also be attributed the fact that the nutrients contained in its tissues are easily decomposed and resealed as plant nutrients in forms that are easily available to plants (PALM 1997). This is because it has a lower concentration of leaf lignin and polyphenol contents (less than 15 and 4%, respectively), so that it decays relatively easily (ICRAF 1997).

Several experiments have been conducted to compare the performance of *Tithonia* biomass with chemical fertilizers. Experimental evidence suggests that addition of N and P through the application of *Tithonia* biomass may increase yields more than the use of equivalent quantities of mineral N and P (JAMA et al. 2000). This has been attributed to the presence of micronutrients such as K, Ca, and Mg and also because of an improvement to soil physical characteristics. One of the pioneer experiments with *Tithonia* in Kenya compared *Tithonia* biomass with Triple Superphosphate (TSP) applied at equal rates of P (ICRAF 1997). Available P was generally comparable following either applications, indicating that Tithonia releases a considerable fraction of its total P as plant-available P. But unlike TSP, *Tithonia* increased soil microbial activity and was more effective in reducing the sorption (fixation) of P by iron and aluminium oxides in the soil. The organic anions released during decomposition compete with P ions for sorption sites therefore making it more available for plant uptake (ICRAF 1997).

Mode of application of organic materials

In all the variables observed, the surface application of plant material (i.e. mulching) was more superior in influencing wheat performance as compared to incorporation at various soil depths. This was followed closely by the shallow incorporation at 15 cm in the case of grain yields. This could be attributed to wheat root morphology of wheat. Wheat are known to have mainly two types of roots; the 3-5 seminal roots which go as deep as 1 m into the soil, and several lateral roots which go up to 15 cm deep. The lateral roots are concentrated within the top 6 - 13 cm of the top soil (KINYUA et al. 2002). The main function of these roots is to absorb nutrients and water. This implied that soil moisture and plant nutrients should be available at these shallow depths in orders to maximize plant growth. The application of organic material as mulch or at 15 cm depth is therefore likely to be the most appropriate depth of application for such a shallow rooted crop as wheat especially in warm environments. Deeper applications like 30 cm are likely to make most of the nutrients to be inaccessible to the plant roots.

Conclusions:

Plant materials with high nutrient concentrations together with can support organically managed wheat crops in Kenya. This is likely to be economically viable for small scale farmers who cannot afford chemical fertilizers due to capital constraints. It may contribute to sustainable soil management in organic wheat production systems. The present research agrees with the findings of other scientists that *Tithonia diversifolia* can provide most of the primary nutrients to crops, particularly nitrogen and potassium. With an addition of phosphorus fertilizer from external sources, *Thithonia* can be as good as a chemical fertilizer and yields that are equivalent to those under chemical fertilizer management can be obtained. The depth of incorporation of plant materials is dependant on, among other factors the root morphology of the crop species, since shallow incorporations are appropriate for shallow rooted crops and vice versa. Future trials should study the effect of incorporation depth on different crop species which have different rooting depths.

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