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Research Article

EFFECT OF WHEAT CROP RESIDUE INCORPORATION WITH THE SOIL AND NITROGEN FERTILIZER RATES ON PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.) VARIETY IN GIBE DISTRICT HADIYA ZONE, SOUTHERN ETHIOPIA

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ABSTRACT. Maize is an important cereal in human diets and animal feed, providing adequate energy and protein. Even though many biotic and abiotic factors can contribute to the big yield gaps, soil fertility depletion, and poor organic and inorganic nutrient management are among the major factors contributing to low productivity. Therefore, this research aims to determine the effect of wheat crop residue incorporation with the soil and nitrogen fertilizer rates on the productivity of maize variety in the study area. The study was conducted in Gibe District, Hadiya Zone, Southern Nations Nationalities, and People Regional State at farmers' fields during the main cropping season in 2022. The treatments consisted of two factors, namely, four levels of nitrogen rates (75 kg ha^{-1}, 100 kg ha^{-1}, 125 kg ha$^{-1,}$ and 150 kg ha^{-1} of N in the form of urea) and five-level wheat residue application rates (control, 2.5t/ha, 3t/ha, 3.5t/ha and 4t/ha). The experiment was laid out in randomized complete block design (RCBD) in 4 x 5 factorial arrangements with three replications. The analysis of variance showed that the maximum grain yield (4.863 t ha^{-1}) was obtained with the highest N rate (150 kg N ha^{-1}), which applied 4 t ha^{-1} of residue incorporation with the soil. While the least value grain yield (2.877 t ha^{-1}) was recorded in plots that received (75 kg N ha^{-1}) applied at 4 t ha^{-1} of residue incorporation with the soil. Like grain yield, the total biomass yield of maize also increased linearly with an increase in nitrogen fertilizer rates. Thus, the results suggested that using 150 kg N ha$^{-1,}$ which applied 4 t ha^{-1} of residue incorporation with the soil, increased the yield of maize in the study area.

Keywords: *Crop residue, maize, nitrogen fertilizer rate, productivity*

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in the world next to rice and wheat and has the highest production potential among the cereals [1]. It is the most important food for humans in South America, Africa and China [2]. Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socioeconomic conditions [3]. It is grown mainly during the main growing season known as *meher*, which relies on May-September rainfall [4]. It is grown from moisture stress to high rainfall regimes and from lowland to the highlands. It is an important cereal in human diets and animal feed, providing adequate amounts of energy and protein [5]. It is also the most important stable crop in terms of calorie intake in Ethiopian rural families. Approximately 88% of maize produced in Ethiopia is used as food, in both green cobs and grain [6]. Maize has expanded rapidly in terms of both area and production. Following the significant increase in maize productivity as a result of the good investment in improved seeds and chemical fertilizers to increase maize production and productivity, maize had a positive impact on poverty reduction in many parts of the country [3].

Maize agronomic research was also initiated shortly after the release of the new maize varieties. The use of crop residues is a valuable agricultural practice, with potential benefits in terms of soil quality and fertility, nutrient and water management. Crop residues are an important source of plant nutrients and organic matter. Long-term residue retention increases soil microbial composition and biomass, promotes soil nutrient recycling, increases the soil organic matter (SOM) content [7], improves soil quality, creates a soil regime favorable for root development, and results in higher crop yields [8]. Crop residue retention is an important component of environmental protection; residues with high lignin content contribute to soil carbon sequestration and lower CO_2 effluxes in the soil [9]. Residue retention has the potential to mitigate the global increase in atmospheric greenhouse gases [10]. The burning of residues contributes to environmental pollution. Therefore, crop residue retention should be promoted to improve soil quality and the environment's health.

Nitrogen use and demand is continuously increasing day by day. Since it is highly mobile, it is subject to greater losses from the soil-plant system [11]. Even under the best management practices, 30-50% of applied N is lost through different agencies and, hence, the farmer is compelled to apply more than the actual need of the crop to compensate the loss [11]. The loss of N not only troubles the farmer, but it has also hazardous impacts on the environment. In high- and medium-altitude maize growing areas where rainfall is high, most of the nitrogen is lost through leaching and denitrification, making the nutrient unavailable during the critical stages of crop growth. Many strategies have been developed to mitigate nutrient leaching and improve the nutrient use efficiency (NUE). Nitrification inhibitors, which slow the oxidation of NH4, and slow- and controlled-release fertilizers have been used to reduce N leaching [12].

Poor soil fertility is a principal factor limiting maize productivity in maize-growing areas of Ethiopia [5, 13]. The continued use of chemical fertilizers leads to a continued decline in soil quality and other environmental problems. For example, the application of nitrogen (N) fertilizers is proven to cause low N use efficiency (NUE) in crops and environmental pollution by the accumulation of NO3–N in the soil [14]. The removed residues are generally used for food and fiber (animal feed and bedding, biofuel production, building materials, household fuel, paper making, and mushroom cultivation), negatively affecting soil fertility, agronomic productivity, and environmental quality [15]. Average productivity of maize is 6.7 t ha^{-1} in developed countries and 2.4 t ha^{-1} in developing countries [2]. Despite the fact that its current productivity is higher than other major cereal crops, the yield productivity is below its potential. For instance, the potential yield of late maturing hybrid maize varieties can produce up to 9.5–12 t ha^{-1} at research field and 6–8.5 t ha^{-1} at an on-farm field (Variety Registration, 2012). Whereas the national average productivity is 3.4 t ha^{-1} while in the SNNPRS is 3.075 t ha^{-1} [16].

In terms of the residue application rates that are recommended this will vary based on a host of variables such as the type of residues, location, time of the year, subsequent crops, and the overall purpose for their use, such as a nutrient amendment, or to establish a mulch for weed control. As a general reference, for regions where farmers often can’t afford the cost of chemical fertilizers, such as in the arid West African Sahel, annual application rates of crop residues of 2,000-4,000 Kg/Ha result in considerable yield increases of 20-400%, but many subsistence farmers are unable to meet these rates, due to the many competing demands or alternative uses for crop residues in that region, such as for fuel, building materials, and feed [17]. Slight, but realistic residue application rates for Africa, to manage erosion are in the range of 0.3 kg/m2 (3,000 kg/Ha), however, even these relatively low rates are often difficult to reach in subsistence agricultural systems [18].

Even though many biotic and abiotic factors can contribute to these big yield gaps, soil fertility depletion and poor nutrient management are among the major factors contributing to low productivity [19]. Nutrient inputs from chemical fertilizers are needed to replace nutrients exported and lost during cropping to maintain positive nutrient balances [20]. Nitrogen is the major macronutrient that is most limiting in maize grain Production worldwide [21]. Nitrogen availability influences the uptake, not only of itself but also of other nutrients [22]. This is partly attributed to better plant growth by which N-fertilized plants have larger root systems to capture other nutrients [23]. In general, maize is one of the main staple crops in the Gibe district, but productivity is diminishing from time to time due to soil fertility problems. The main cause of the problem in the area is that almost all farmers use wheat crop residue for feed, bedding, and construction purposes rather than considering it as an organic fertilizer for soil fertility. Subsistence farmers cannot purchase inorganic fertilizers, and blanket application of N fertilizer (more or less than the actual need of the crop) are the factors affecting the district's considerable yield. Therefore, this study aimed to determine the effect of wheat crop residue incorporation with the soil and nitrogen fertilizer rates on the productivity of maize variety in the study area.

MATERIAL AND METHODS

Description of the Experimental Sites

The study was conducted in Gibe District at farmer’s field during the main cropping season of 2022. The Gibe district is located at Hadiya Zone in the country's Southern Nation Nationalities and People regional state /SNNPRS/. It is situated 260 Km south of Addis Ababa and 30 Km Southwest of Hossana town. Geographically it lies at 70˚ 37’53” -70˚ 42’43’’N Latitude and 37˚ 37’07’’-37˚ 44’25’’ E longitudes. The total area of Gibe district is 44783 ha. Gibe district has Kola, Woynedega, and Dega climatic characteristics, with the mean annual rainfall ranging from 600 to 1200mm. The rainfall in the district is bimodal, which is locally called Belg and Meher. The mean annual temperature ranges from 17.6°C to 25°C. The altitude of 1200 – 2500 m.a.s.l. The area coverage of the land use system indicates that 69.8% is cultivated lands, 14.5% is forest lands, 8.4% is grazing lands and 7.3% is others. The main annual crops grown in the area under the rain-fed system are wheat (*Triticum aestivum* L), barley, maze (*Zea mays* L.), Teff (*Eragrostis teff*) sorghum, Potato, Bean and pea [24].

Experimental Materials

The variety BH661 (Bako hybrid) seed was used from a southern agricultural seed multiplication center as experimental materials, which was considered a quality seed. The seeds of the variety were used from the 2021 cropping season harvest.

Treatments and Experimental Design

The treatments consisted of two factors. Namely, four levels of nitrogen rates (75 kg ha^{-1}, 100 kg ha^{-1}, 125 kg ha^{-1} and 150 kg ha^{-1} of N in the form of urea) and five-level wheat residue application rates (control, 2.5t/ha, 3t/ha, 3.5t/ha and 4t/ha) incorporated with the soil two weeks before sowing of seeds. The experiment was laid out in randomized complete block design (RCBD) in 4 x 5 factorial arrangements with three replications. In this experiment, the total number of treatments and plots were 20 and 60; respectively. The size of each experimental plot was 3 m long and 3 m wide, Plant population for all experimental plots were 2400 plants, 75 cm between rows and 30 cm between plants with 4 rows of 75 cm apart, giving a gross plot area of 9 m^2. Spacing of 1.5 m and 1 m was maintained between adjacent blocks and plots, respectively. All data except phenology of crop were collected from the middle two rows leaving the outermost two rows in both sides, and plants that were grown at 37.5 cm extreme most distance at both ends of rows. Thus the net harvestable plot area was 6.075 m^2 (2.25 m x 2.70 m) and total harvestable area was 364.5 m^2. The total size of the plot and area of the field was 540 m^2 (9 m^2 x 60) and 948 m^2 (79 m x 12 m) respectively.

Study Methodology

Land preparation

The experimental field was prepared following the conventional tillage practice which includes 2-3 times plowing before planting of the maize variety BH661 (bako hybrid) seeds. As per the specifications of the design, a field layout was prepared; the land was cleaned, leveled and it was made suitable for crop establishment.

Sowing and field management

Sowing was done in May 2022, and it was made by keeping two seeds in one hill at a distance of 30 cm within a row. Two weeks after emergence, plants were thinned to one plant per hill. Recommended phosphorus (100 kg P ha^{-1}) in the form of triple superphosphate (TSP) for all experimental plots including control plot was equally and uniformly applied at the time of maize planting. The wheat crop residues were incorporated with the soil in the depth of 10-20cm in one to two weeks before sowing of maize crop as per treatment arrangements and the rate of application of nitrogen fertilizer was applied in the form of UREA as per treatment arrangements. One hybrid late maturing variety BH661 (Bako hybrid) of maize was used for the execution of the treatments. While conducting the experiment others necessary agronomic management practices such as weeding, disease and insect pest control were carried out uniformly for all treatments to evaluate the performance of productivity of maize variety.

Data Collection and Measurements

Data collection was carried out during the vegetative period, at harvest and after harvest. The Data was collected on agronomic parameters (plant height, Days to silking, Days to physiological maturity), yield components (Numbers of grain rows per ear, number of grains per ear and 1000-grain weight), yields (grain, dry biomass, and harvest index).

Plant height

Plant height from the ground level up to the collar of the upper leaf with developed leaf sheath was measured at physiological maturity time.

Days to 50% silking

Tasseling was reached when 50% of the plants shed pollen from the main branch of the tassel and from a few other branches. Silking refers to the stage when silk was emerged on 50% of the observed plants. Silking date was record¬ed when 50% of the plants had extruded silks.

Days to 90% physiological maturity

The appearance of a black layer underneath the tip of the kernel that is attached to the cob was used as a criterion for physiological maturity. It was determined by counting the number of days from the planting date to harvesting time.

Numbers of grain rows per ear

Five randomly selected ears was harvested in each plot and numbers of rows per each ear was counted and averaged.

Number of grains per ear row

The number of grains per ear row was determined by counting the number grains in one row of each harvested ears and averaged.

Thousand grain weights

Thousand-grain weight was determined by weighing with analytical balance the weight of 1000 sampled grains from the bulk harvest and adjusting to 12.5 % moisture level.

Grain and biomass yield

Grain and stubble yield data was collected from the two harvestable rows by excluding over-favored plants (plants that stand at a spacing exceeding the required distance due to missing plants in a row). The harvested biomass was weighed for fresh biomass weight after which the ears and the stubble are separated and weighed. The ears are shell and grain yield was determined by adjusting to 12.5 % moisture content. Stubble of two stands from each plot was collected from each plot at harvest. The stubble samples are sun dried until constant weight was attained so that it was possible to calculate the dry stubble yield per plot. The dried biomass yield was determined as the sum of dry grain and dry stubble yields.

The harvest index (HI)

It was computed as the grain yield (GY) ratio to the total above-ground Dry-mass (DM) yield. The following formula was used: HI (%) = (grain yield/total biological yield) × 100.

RESULT AND DISCUSSION

Days to 50% silking

Statistical analysis of the data revealed that the interactions of N rates and wheat crop residue incorporation with the soil are not significant. But, the main effect of N-rates showed significant at ($P<0.05$) on days to 50% silking. The highest value recorded at N-rate of 75 kg ha^{-1} and minimum value recorded at N-rate of 150 kg ha^{-1} (table 1). The result indicated that increases N-rate shorten the duration of 50% silking time. This decrease may be due to enhanced growth rate and dry matter accumulation in an early stage. The shorten duration in silking period in response to increasing in N rate might be attributing to rapidness in growth period and promoting silk extrusion. Similar results also reported by [25] reported that the mean values for nitrogen rates showed that days to 50% silking delayed by 2 days in a treatment with no N application compared to a treatment that fed with 115 kg N ha^{-1}. Thus the maximum days to 50% silking (84.67) were recorded in a plot with no N application. However, it was statistically similar with days to 50% silking recorded under a treatment of 23, 46 and 69 kg ha^{-1} N-rates. The minimum days to 50% silking (82.67) were obtained under maximum N rate (115 kg N ha^{-1}) But statistically similar result were also obtained under application of 46, 69 and 92kg N ha^{-1}. However, there was a decreasing trend in days to 50% silking with increasing in nitrogen rates. But, the result was not agreed with that of [26] who reported that the maximum days to silking (56.37 DAS) were taken by the crop when N dose was applied at the rate of 250 kg ha^{-1}, followed by N5 (300 kg N ha^{-1}) while minimum days to silking (52.50 DAS) were observed for N1 (100 kg ha^{-1}) treatment, mean days to silking was 54.62 DAS.

Days to 90% Physiological Maturity (DPM)

The data, along with the comparison of means, are presented in Table 1, which indicates that Days to 90% physiological maturity showed significant ($P<0.01$) differences between N-rates (Table 2). However, the interaction of N-rate and wheat crop residue incorporation with the soil showed no significant variation on days to 90% physiological maturity. In addition, N- fertilizer applied at 150 kg ha^{-1} was found late maturing, which took the longest duration (131.9 days), and N- fertilizer applied at the rate of 75 kg ha^{-1} took the shortest duration (128.8 days). This might be the difference in N fertilizer rates' mineralization and nutrient accumulation. This might also be due to the loss of water content in seeds obtained from N-fertilizer applied at the rate of 75 kg ha$^{-1,}$ as it was observed from the rapid change of plants from green color to yellowish at field evaluation and the appearance of a black layer underneath the tip of the kernel that is attached to the cob early appeared than the other rate of application. This result was in agreement with that of [27], who reported that the maximum days to physiological maturity (141.7 days after sowing, DAS) was achieved by N3 (69 kg ha^{-1}), followed by N2 (135 days) where N was applied at the rate of 46 kg ha-1. Delay in the maturity of maize was greater at the higher rate of N, as about 16 more days were required for the 69 kg ha-1 treatment compared to the control, which took 125 days to maturity. This might be attributed to the behavior of N-fertilizer, which increases the vegetative growth of the cob when more N is applied.

***Table 1.** The main effect of nitrogen fertilizer rate on Days to 50% silking and Days to 90% Physiological Maturity (DPM) of maize*

N- Rate (kg ha^{-1})	Mean values of parameters	
	DS (days)	DPM (days)
75	75.60 ^{a}	128.8 ^{b}
100	74.73 ^{ab}	128.3 ^{b}
125	74.00 ^{bc}	131.3 ^{ab}
150	73.67 ^{c}	131.9 ^{a}
LSD (5%)	0.979	2.930
CV (%)	1.8	3.1

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent, DS= Days to 50% silking and DPM= Days to 90% Physiological Maturity

Plant Height

The analysis of variance showed that the main factors (N rate and crop residue application) and their interaction of these factors significantly influenced plant height (Table 2). It increased with increasing N rates. So, the maximum plant height (2.25 m) was obtained with the highest N rate (150 kg N ha^{-1}) when 4 t ha^{-1} crop residue was incorporated with the soil in the plot. The least value (1.67 m) was recorded in plots that received (75 kg N ha^{-1}) with no crop residue application (Table 3). The results of the present study was in close agreement with [28] which revealed that the plant height and grain production of maize crops had highest observed by incorporating residue with a combination of tillage. [29] those also stated that the increased in plant height maize crop was due to prolonged vegetative growth which increase the plant height. This tendency can be attributed to higher dose of N, which greatly helps the plant to expose its potential to grow vigorously. The study also in-line with that of [30] who stated that when the wheat residue was incorporated with conventional tillage practices, the difference was detected in plant height as compared to other treatments, the maximum height of plant were (107 cm) observed in Conventional tillage + wheat residue incorporation rate 02 ton.ha^{-1} and minimum (90.9 cm) were in Reduced tillage.

Table 2. *Mean squares of analysis of variance for yield components and yield parameters of maize from different N-rate and wheat crop residue application*

Source of Variation	DF	Mean squares DT	 DS	 TSI	 PH	 DPM
Replication	2	1.117	2.600	0.716	0.00017	16.02
NR	3	2.000 ^{ns}	11.044 *	18.511**	0.10857**	48.84*
WCR	4	0.525 ^{ns}	1.250 ^{ns}	3.025^{ns}	0.10857**	36.97*
NR×WCR	12	1.181 ^{ns}	1.406 ^{ns}	2.303*	0.03833*	19.61^{ns}
Residual	38	1.590	1.968	0.717	0.01423	12.68
CV (%)		1.8	1.9	19.4	6.4	2.7

* and **, significant at 5% and 1% level of significance, respectively, ns = None significant difference, CV (%) = coefficient of variation in percent, DF = degree of freedom, NR = nitrogen fertilizer rate, WCR = wheat crop residue, DT = days to 50% tasseling, DS = days to silking, TSI = days to 50% tasseling –silking interval, PH = plant height and DPM = days to physiological maturity.

Table 3. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on plant height of maize*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	1.650 ^{i}	1.873 ^{cdefghi}	1.763 ^{efghi}	1.687 ^{hi}	1.803 ^{cdefghi}
100	1.683 ^{hi}	1.747 ^{ghi}	1.983 ^{bcde}	1.917 ^{cdefgh}	1.847 ^{cdefghi}
125	1.750 ^{eghi}	1.870 ^{cdefghi}	1.827 ^{cdefghi}	2.000 ^{bc}	1.947 ^{bcdefg}
150	1.768 ^{cefghi}	1.983 ^{bcdef}	2.160 ^{ab}	2.000 ^{bcd}	2.250 ^{a}
LSD (5%)			0.1972		
CV (%)			6.4		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Number of Grain Rows Ear^{-1}

Statistical analysis revealed that the number of grain rows ear^{-1} was highly significantly affected by the main factor and their interaction (Table 4). A high number of grain rows ear^{-1} (12) was recorded in the plots treated with 125 kg N ha^{-1} and 3.5 t ha^{-1} of crop residue application, and the Minimum number of grain rows ear^{-1} (10) was recorded in 75 kg N ha^{-1} with no application of crop residue (Table 5). Similar results have been reported by [31], who also reported that increasing the N fertilizer rate increased the number of grain rows per ear, resulting in higher grain yield compared with their control (no N application).

Table 4. *Mean squares of analysis of variance for yield components and yield parameters of maize from different N-rate and wheat crop residue application*

Source of Variation	DF	Mean squares NRPE	NGPER	TKW	GY	BY	HI
Replication	2	0.0167	2.017	183.8	0.16400	0.9425	0.050
NR	3	5.2000**	50.950**	1374.5**	3.25047**	32.4542**	4.941^{ns}
WCR	4	2.8083**	32.567**	1984.9**	1.57558**	19.2459**	5.024^{ns}
NR×WCR	12	0.5750**	10.700**	968.7**	0.14456**	8.9374**	27.875**
Residual	38	0.1044	1.701	210.4	0.03840	0.3116	4.050
CV (%)		3.0	4.5	5.9	4.9	4.2	6.6

* and **, significant at 5% and 1% level of significance, respectively, ns = None significant difference, CV (%) = coefficient of variation in percent, DF = degree of freedom, NR= nitrogen fertilizer rate, WCR = wheat crop residue, NGRPE = number of grain rows per ear, NGPER = number of grains per ear rows, TKW = thousand kernel weight, GY = grain yield, BY = biomass yield and HI = harvest index.

Table 5. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on the number of grain rows per ear of maize*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	10.00 ^{d}	10.33 ^{cd}	10.33 ^{cd}	10.00 ^{d}	10.00 ^{d}
100	10.00 ^{d}	11.00 ^{b}	11.00 ^{b}	12.00 ^{a}	11.00 ^{b}
125	10.33 ^{cd}	10.67 ^{c}	11.67 ^{b}	12.00 ^{a}	12.00 ^{a}
150	10.33 ^{cd}	12.00 ^{a}	11.00 ^{b}	12.00 ^{a}	12.00 ^{a}
LSD (5%)			0.5340		
CV (%)			3.0		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Number of Grains per Ear Row

The analysis of data regarding the effects of N rates and crop residue incorporation with the soil on the number of grains per ear row is given in Table 6. High number of grains per ear row (35.33) was recorded in the plots treated with 150 kg N ha^{-1} and 4.0 t ha^{-1} of crop residue incorporation with the soil. In contrast, the lower number of grains per ear row (25.67) was recorded in 75 kg N ha^{-1} with 4.0 t ha^{-1} of wheat crop residue incorporation with the soil. A greater number of grains per ear row with higher N rates might have resulted from the greater assimilates partitioning to the seeds due to a longer growth period and higher photosynthetic availability during the grain filling period. Similar results have been reported by [4], suggesting that a decrease in the number of grains per ear row under lower N application might be attributed to poor sinks development and reduced photosynthesis translocation. In this study, high N rates delayed the appearance of phonological stages, which seems to be one of the reasons for increasing the number of grains per ear row. The result also agreed with [32], who stated that the increase in a number of grains cob^{-1} under Conservation tillage and wheat residue may be due to conducive soil condition for plant growth and development. Grains cob^{-1} can be increased due to proper tillage and mulching practices. With favorable soil tilth, suitable moisture conservation, root growth, nutrients can enhance grains cob^{-1} with the use of proper tillage practices [30].

Table 6. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on number of grain rows per ear of maize*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	25.67 ^{f}	25.67 ^{f}	27.67 ^{cdef}	29.00 ^{cde}	25.67 ^{f}
100	26.67 ^{ef}	27.33 ^{def}	32.00 ^{b}	29.33 ^{cd}	26.67 ^{ef}
125	26.67 ^{ef}	28.00 ^{cdef}	27.33 ^{def}	32.00 ^{b}	30.00 ^{bc}
150	27.33 ^{def}	29.33 ^{cd}	32.00 ^{b}	32.00 ^{b}	35.33 ^{a}
LSD (5%)			2.156		
CV (%)			4.5		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Thousand Kernel Weight (g)

The analysis of variance of the interaction effect of N rates and residue incorporation with the soil showed a highly significant difference ($P<0.01$) on the thousand kernel weight of treatment means (Table 7). However, the time of N application and the interaction effect showed no significant variation between treatment means. The comparison of means indicated that the maximum thousand kernel weight (271.7 g) was recorded at the application of 150 kg N ha$^{–1}$ with 3.5 t ha^{-1} of crop residue incorporation with the soil, and the minimum value of thousand kernel weight (175.0 g) was recorded the application of 125 kg N ha$^{–1}$ applied in control or 0 t ha^{-1} of crop residue incorporation with the soil. This is due to a higher photosynthesis rate which increases the size of kernel weight and leads to increase grain yield. The result of the analysis also agreed with [30] who stated that the combined effect of tillage and residue on weight of thousand grains were found significant ($p<0.05$). In addition, from the results it is observed that the performance of maize crop significantly ($p\leq0.05$) improved each year by using crop residue incorporation and tillage methods. The conventional treatment with mulching provides a favorable environment for plant growth, better root development, and plant populations, which gave better results as compared to no-mulch. Conventional tillage practices increased the thousand grain weight as compared to shallow tillage in maize plant similarly, [33] indicated that higher rate of N level increased kernel weight in maize might be due to relatively higher amount of photosynthesis to the grains.

Table 7. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on thousand kernel weight (g) of maize*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	245.0 ^{abc}	240.0 ^{bc}	245.0 ^{abc}	238.3 ^{c}	240.0 ^{bc}
100	238.0 ^{c}	250.0 ^{abc}	245.0 ^{abc}	250.0 ^{abc}	244.0 ^{abc}
125	175.0 ^{d}	246.7 ^{abc}	263.3 ^{abc}	263.3 ^{abc}	263.3 ^{abc}
150	243.3 ^{abc}	260.0 ^{abc}	268.3 ^{ab}	271.7 ^{a}	266.7 ^{abc}
LSD (5%)			23.97		
CV (%)			5.9		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Grain Yield

The analysis of variance revealed that the main factors (N rate and wheat crop residue incorporation with the soil) and their interaction of these factors were highly significant influenced grain yield (Table 4). It increased with increasing N rates. So, the maximum grain yield (4.863 t ha^{-1}) was obtained with the highest N rate (150 kg N ha^{-1}) which applied 4 t ha^{-1} of residue incorporation with the soil. While the least value (2.877 t ha^{-1}) was recorded in plots which receive (75 kg N ha^{-1}) which applied 4 t ha^{-1} of residue incorporation with the soil (Table 10). The result is in agreement with the result of [34] who reported that the positive effects of residue application on the crop yield and soil productivity. The effect of crop residue on grain yield could have been related to the soil water content and water use efficiency [35]. Maize production /yield can be significantly increased by application of mulching on soil. Similarly, [36] gained the yield variation between 4744.8 kg ha^{-1} without N application to 7355.5 kg ha^{-1} at application of 225 kg N ha^{-1}. These results indicated that N application with increase in split application proved an additional source for a higher rate of photosynthesis and transport of photo-assimilates during grain filling that resulted in a higher grain yield of maize. The amount of crop residue probably improved soil infiltration, reduced soil water evaporation and increased soil moisture, thus increases grain yield with increases of N rates and residue incorporation. The increase in yield of the maize with increasing N rates with respect to crop residue incorporation with the soil might be due to the role of N in increasing the leaf area and promote photosynthesis efficiency which promote dry matter production and increase yield (table 6). A recent study was also in lined with [37] who reported that grain yield of maize substantially declined to only 1.62 t ha^{-1} when no N was applied, while higher yields of 4.72 to 4.88 t ha^{-1} were obtained with 120 to 180 kg N ha^{-1}. These results are in agreement with [38] who reported that crop residues incorporation significantly increased grain yield of maize compared with the residues removed treatment. They further added that on average, crop residues increased the grain yield of maize by 23.7%. Similarly, [39] also reported an increase in cereal grain and stover yields by 37 and 49%, respectively, when crop residues were incorporated compared with untreated controls (no residues incorporation).

Table 8. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on grain yield of maize (t ha^{-1})*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	2.877 ^{h}	3.600 ^{fg}	3.440 ^{g}	3.800 ^{e}f	3.333 ^{g}
100	3.357 ^{g}	3.797 ^{ef}	4.150 ^{de}	250.0 ^{abc}	3.907 ^{ef}
125	3.400 ^{g}	4.410 ^{bcd}	4.283 ^{cd}	4.550 ^{abc}	4.730 ^{ab}
150	4.067 ^{de}	4.150 ^{de}	4.540 ^{abc}	4.740 ^{ab}	4.863 ^{a}
LSD (5%)			0.3239		
CV (%)			4.9		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Biomass Yield (t ha^{-1})

Data subjected to analysis of variance and the result indicated that the main factors (N- rate and crop residue incorporation with the soil) and their interaction were significantly influenced biomass yield (Table 4). It increased with increasing N rates. So, the maximum biomass yield (17.71 t ha^{-1}) was obtained with the highest N rate (150 kg N ha^{-1}) at 3.5 t ha^{-1} of crop residue was incorporated with the soil. While the statistically the least value (8.83 t ha^{-1}) was recorded in plots which receive (75 kg N ha^{-1}) which applied at 0 t ha^{-1} or no incorporated crop residue with the soil (Table 9). The biomass yield production was largely a function of photosynthetic surface, which was favorably influenced by N-fertilization. So, the increasing fertilization of N-rate from 75 to 150 kg ha^{-1} relatively increases the biomass yield production in the study area. Like grain yield, total biomass yield of maize also increased linearly with increased in N rates from 75 to 150 kg N ha$^{-1,}$ showing more dry matter allocation in favor of the Stover under heavier N rates. Also, the increased in total biomass is directly related to the increase in plant height, leaf area, and vegetative growth which is due to sufficient availability of N to the plants. In agreement with the results of this study, [40, 34] reported significantly higher biomass yield at higher N rates. [41] also reported that grain yield of maize increase progressively with added nitrogen fertilizer up to a certain rate. Biological yield increase with increase in N-levels because of more growth occur which results in increased in biological yield. The other result from [2] reported that the highest significant biomass yield (21.2 tha^{-1}) was obtained at 115 N kg ha−1 and T4 (four times split application of equal doses) followed by 69 N kg ha^{-1} at T1 and T2. However, application of 46 kg ha^{-1} at T2 (two times split application of equal doses) showed the lowest yield, except the control plot without N, compared to other treatment combinations.

Table 9. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on biomass yield of maize (t ha^{-1})*

	Crop residue rate (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	8.83 ^{g}	14.74 ^{bc}	11.79 ^{e}	11.47 ^{ef}	11.19 ^{ef}
100	10.68 ^{f}	11.45 ^{ef}	15.34 ^{b}	15.03 ^{bc}	11.65 ^{ef}
125	11.04 ^{ef}	13.48 ^{d}	14.04 ^{cd}	15.40 ^{b}	15.32 ^{b}
150	15.00 ^{bc}	13.33 ^{d}	13.73 ^{d}	17.71 ^{a}	15.52 ^{b}
LSD (5%)			0.9227		
CV (%)			4.2		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Harvest Index

The analysis of variance revealed that the interaction of N rate and wheat crop residue incorporation with the soil had significant difference for the harvest index. But, both main factors showed non-significant variation between treatment means. The comparison of means indicated that the maximum harvest index (33.60 %) was recorded at application of 100 kg N ha$^{–1}$ at 4 t ha^{-1} wheat crop residue incorporated with the soil and the minimum value (24.41 %) was recorded at application of 75 kg N ha$^{–1}$ at 2.5 t ha^{-1} wheat crop residue incorporated with the soil (Table 8). The result is in lined with the result of [43] those reported that the harvest index in corn increases when N rates increase. However, delayed application of N after crop establishment (split application) significantly increased harvest index (HI) compared to N application at the time of planting. The other result [44] also reported that the maximum harvest index (36.1%) was recorded from 120 kg ha^{-1} nitrogen application, followed by 90 kg N ha^{-1} (33.6%) over the minimum (31.6%) observed from control. The increased harvest index with higher levels of N might be due to efficient portioning of assimilates towards the economic portion. The result also agreed with [45] who reported that the high harvest index (HI) obtained from the combined application of crop residue and inorganic fertilizer treatments was due to efficient utilization of nutrients, which increased the rate of conversion of dry matter into economic yield. Also, the increase in kernel per cob and better green cob yield in the combined application of organic and inorganic fertilizer led to a higher HI.

Table 10. *Interaction effect of nitrogen fertilizer rate and crop residue incorporation with the soil on harvest index of maize (%)*

	Crop residue (t ha^{-1})				
N- Rate (kg ha^{-1})	0	2.5	3	3.5	4
75	33.13 ^{abc}	24.41 ^{f}	29.23 ^{cde}	33.13 ^{abc}	29.80 ^{abcde}
100	31.37 ^{abc}	33.25 ^{ab}	27.05 ^{def}	29.40 ^{bcde}	33.60 ^{a}
125	30.69 ^{abcd}	32.72 ^{abc}	30.60 ^{abcde}	29.55 ^{bcde}	30.87 ^{abcd}
150	27.11 ^{def}	31.18 ^{abc}	33.08 ^{abc}	26.78 ^{ef}	31.35 ^{abc}
LSD (5%)			3.327		
CV (%)			6.6		

Means with the same letter (s) in the same column and rows of the trait are not significantly different at 5% probability level, t ha^{-1} = tone per hectare, kg ha^{-1} = kilogram per hectare, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

CONCLUSION

The study was conducted in Gibe District at farmer's field during the main cropping season of 2022 with the general objective to determine effect of wheat crop residue incorporation with the soil and nitrogen fertilizer rates on productivity of maize variety. The results of analysis indicated that the grain yield production was largely a function of photosynthetic surface, which was favorably influenced by N-fertilization. So, the increasing fertilization of N-rate from 75 to 150 kg ha^{-1} relatively increases the grain yield production in the study area. It increased with increasing N rates. So, the maximum grain yield (4.863 t ha^{-1}) was obtained with the highest N rate (150 kg N ha^{-1}) which applied 4 t ha^{-1} of wheat crop residue incorporation with the soil. While the least value (2.877 t ha^{-1}) was recorded in plots which receive (75 kg N ha^{-1}) which applied 4 t ha^{-1} of wheat crop residue incorporation with the soil. These results indicated that N application with increase in split application proved an additional source for a higher rate of photosynthesis and transport of photo-assimilates during grain filling that resulted in a higher grain yield of maize. The amount of crop residue probably improved soil infiltration, reduced soil water evaporation and increased soil moisture, thus increases grain yield with increases of N rates and residue incorporation. The increase in yield of the maize with increasing N rates with respect to crop residue incorporation with the soil might be due to the role of N in increasing the leaf area and promote photosynthesis efficiency which promote dry matter production and increase yield. These results suggested that the importance of using appropriate N-rate and wheat residue incorporation rate was used to increase yield of maize in the study area. However, the experiment was conducted considering only one variety at one location which might be not represent all maize growing areas of southern Ethiopia. Therefore, it is necessary to conduct the experiments considering more number of varieties and different rates of wheat crop incorporation with the soil at major maize growing areas for more than one cropping seasons to make conclusive recommendation that can be applicable in Gibe District, southern Ethiopia.

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REFERENCES

[1] Zamir M.S.I., Yasin G., Javeed H.M.R., Ahmad A.U.H., Tanveer A., Yaseen M., (2013): Effect of different sowing techniques and mulches on the growth and yield behavior of spring planted maize (Zea mays L.). Cercetări Agronomice în Moldova, 1(153): 77-82.

[2] Khalily M, Moghaddam M, Kanouni H, Asheri E. (2010): Disections of Drought Stress as a Grain Production Constraint of Maize in Iran. Asian J. Crop Sci. 2(2):60-69.

[3] Tsedeka Abate, Monica Fisher, wonishet Asnake and Girma T Kasie. (2017): Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow? PMID: 32983427 PMCID: PMC7507799 DOI: 10.1186/s40066-017-0108-6.

[4] Dawadi DR, Sah SK. (2012): Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. Trop Agric Res. 23(3): 218–27.

[5] Wondesen T, Sheleme B. (2011): Identification of Growth Limiting Nutrients in Alfisols: Soil Physico-chemical Properties, Nutrient Consentrations and Biomass Yield of Maize. Am. J. Plant Nutr. Fertili. Technol. 1(1):23-35.

[6] Mandefro, N. Tanner, D. and Twumasi-Afriyie, S. (2001): "Enhancing the contribution of maize to food security in Ethiopia in," in Proceedings of the Second National Maize Workshop of Ethiopia, pp. 12–16, Addis Ababa, Ethiopia, 2001.

[7] Liu DH, Shu L, Chen Q, Chen SH, Chen HL, Zhu ZL. (2011): Effects of straw mulching and little- or zero-tillage on microbial diversity and biomass C and N of alluvial soil in Chengdu Plain, China. Chin J Appl Environ Biol 17:158–161 (in Chinese with English abstract)

[8] Zhao P, Chen F. (2008a): Effects of straw mulching plus nitrogen fertilizer on nitrogen efficiency and grain yield in winter wheat. Acta Agron Sin 34:1014–1018. doi:10.3724/SP.J.1006.2008.01014 (in Chinese with English abstract)

[9] Dong W, Hu C, Chen S, Zhang Y. (2009): Tillage and residue management effects on soil carbon and CO2 emission in a wheat–maize double-cropping system. Nutr Cycl Agroecosyst 83:27–37. doi:10.1007/s10705-008-9195-x

[10] Young LM. (2003): Soil carbon sequestration in agriculture: the U.S. policy in context. Amer J Agr Econ 85:1164–1170

[11] Abd El-Lattief, EA. (2011): Nitrogen management Effect on the Production of Two Sweet Sorghum Cultivars underArid Regions Conditions. Asian J. Crop Sci. 3(2):77-84.

[12] Sitthaphanit S, Limpinuntana V, Toomsan B, Panchaban SW Bell R. (2010): Growth and Yield Responses in Maize to Split and Delayed Fertilizer Applications on Sandy Soils Under High Rainfall Regimes. Kasetsart J. (Nat. Sci.) 44: 991 – 1003.

[13] Abebayehu A, Eyasu E, Diels, J. (2011): Comparative Analysisof Soil Nutrient Balance at Farm Level: A case Study in Jimma Zone, Ethiopia. Inter. J. Soil Sci. 6(4): 259-266.

[14] Zhao P, Chen F (2008a): Effects of straw mulching plus nitrogen fertilizeron nitrogen efficiency and grain yield in winter wheat. Acta AgronSin 34:1014–1018. doi:10.3724/SP.J.1006.2008.01014 (in Chinese with English abstract)

[15] Maw Maw Tun, Dagmar Juchelkova, Myo Min Win, Aung Myat Thu 4 and Tomáš Puchor. (2019): Biomass Energy: An Overview of Biomass Sources, Energy Potential, and Management in Southeast Asian Countries

[16] Central Statistical Agency. Central Statistical Agency, Federal Democratic Republic of Ethiopia; Addis Ababa: (2016): Agricultural Sample Survey 2015/2016, Vol. 1: Area and Production of Major Crops.

[17] [Schlecht, E., Buerkert, A., Tielkes, E. (2006): A critical analysis of challenges and opportunities for soil fertility restoration in Sudano-Sahelian West Africa. Nutr Cycl Agroecosyst 76, 109–136 (2006). https://doi.org/10.1007/s10705-005-1670-z

[18] Schmengler, A.C. (2011): Modeling soil erosion and reservoir sedimentation at hillslope and catchment scale in semi- arid Burkina Faso. ZEF. Inaugural-Dissertation zur Erlangung des Grades Doktor der Agrarwissenschaften (Dr. agr.).

[19] Mourice, S. K. Tumbo, S. D. Nyambilila, A. and. Rweyemamu, C. L. (2015): "Modeling potential rain-fed maize productivity and yield gaps in the Wami River sub-basin, Tanzania," Acta Agriculturae Scandinavica Section B: Soil and Plant Science, vol. 65, no. 2, pp. 132–140.

[20] Buah SSJ, Mwinkaara S. (2009): Response of Sorghum to Nitrogen fertilizer and Plant density in the Guinea savanna Zone. J. Agron. 8(4):124-130.

[21] Hefny M, Aly AA. (2008): Yielding Ability and Nitrogen Use Efficiency in Maize Inbred Lines and Their Crosses. Inter. J. Agric. Res. 3(1):27-39.

[22] Onasanya RO, Aiyelari OP, Onasanya A, Nwilene FE, Oyelakin OO. (2009): Effect of Different Levels of Nitrogen and Phosphorous Fertilizers on the Growth and Yield of Maize (Zea mays L.) in Southwest Nigeria. Int. J. Agric. Res. 4(6): 193-203

[23] Masaka J. (2006): The Effect of N Fertilizer Placement and Timing on the Aboveground Biometric Characteristics of Spring Wheat (Triticum aestivum L.) on Leached Chernozem. Int. J. Agric. Res. 1(1): 68-75.

[24] Gibe District Agricultural office. (2022): Crop production and protection office.

[25] Begizew Golla and Desalegn Chalchisa. (2018): Response of maize phenology and grain yield to various nitrogen rates and plant spacing at Bako, West Ethiopia.

[26] Khan S, Khan A, Jalal F, Khan M, Khan H. (2017): Dry Matter Partitioning and Harvest Index of Maize Crop as Influenced by Integration of Sheep Manure and Urea Fertilizer. Adv Crop Sci Tech 5: 276. doi: 10.4172/2329- 8863.1000276.

[27] Yacob Alemayehu and Meshu Shewareg. (2015): Growth and yield response of maize (*Zea mays* L.) to different nitrogen rate under rain-fed condition in Dilla area, Southern Ethiopa

[28] Vetsch, J.A., Randall, G.W. (2002): Corn Production as Affected by Tillage System and Starter Fertilizer. Agronomy. 94, 532–540

[29] Alemayehu Adinew and Mulugeta Abebe. (2022): Influence of Nitrogen Fertilizer Rate and Its Time of Application on Productivity of Maize (*Zea mays L.*) In Southern Ethiopia.

[30] Sher Ali Shaikh, Li Yaoming, Farman Ali Chandio, Mazhar H. Tunio Fiaz Ahmad1, Irhsad Ali Mari, Kashif Ali Solangi. (2020): Effect of wheat residue incorporation with,tillage management on physico-chemical properties of soil and sustainability of maize production.

[31] Tejada, M. and J.L. Gonzalez. (2003): Effects of the application of a compost originating from crushed cotton gin residues on wheat yield under dry land conditions. Eur. J. Agron., 19: 357-368.

[32] Karami, A., Homaee, M., Afzalinia, S., Ruhipour, H. and Basirat, S. (2012): Organic Resource Management: Impacts on Soil Aggregate Stability and Other Soil Physicochemical Prop- erties. Agriculture, Ecosystems and Environ- ment. 148(4): 22–28.

[33] Abera K. (2013): Growth, productivity and nitrogen use efficiency of maize (Zea maysL.) as influenced by rate and time of nitrogen fertilizer application in Haramaya District, Eastern Ethiopia.

[34] Zhang, P., Wei, T., Jia, Z., Han, Q. and Ren, X. (2014): Soil Aggregate and Crop Yield Changes with Different Rates of Residue Incorporation in Semiarid Areas of Northwest China. Geoderma. 230, 41-49.

[35] Sadeghi, H. (2007): Effects of crop residue and nitrogen rates on morphophysiological traits, yield and yield components of two dryland wheat cultivars. Ph.D. Thesis, Shiraz University, Shiraz, Iran. (In Farsi with English abstract).

[36] Raouf Seyed Sharifi and Ali Namvar. (2016): Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.)

[37] Ahmad, S.; Khan, A.A.; Kamran, M.; Ahmad, I.; Ali, S.; Fahad, S. (2018): Response of maize cultivars to various nitrogen levels. Eur. J. Exp. Biol. 8, 1–4. [Google Scholar] [CrossRef].

[38] Shafi, M. J. Bakht, M.T. Jan and Z. Shah. (2007): Soil C and N dynamics and maize (Zea may L.) yield as affected by cropping systems and residue management in North-western Pakistan. Soil & Tillage Res., 94: 520-529.

[39] Kouyate, Z., K. Franzluebbers, A.S.R. Juo and L. Hossner. (2000): Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant and Soil, 225: 141-151.

[40] Hammad H, Khaliq T, Farhad W. (2011): Optimizing rate of nitrogen application for higher yield and quality in maize under semiarid environment. Agro Climatology Laboratory, Department of Agronomy, University of Agriculture, Faisalabad

[41] Workayehu T. (2000): Effect of N fertilizer rates and plant density on grain yield of maize. Afr Crop Sci J 8(3):273–282

[42] Zerihun Abebe and Hailu Feyisa. (2017): Effects of Nitrogen Rates and Time of Application on Yield of Maize: Rainfall Variability Influenced Time of N Application.

[43] Lawrence JR, Ketterings QM, Cherney JH. (2008): Effect of nitrogen application on yield and quality of corn. Agron J. 100(1): 73–9.

[44] Khan S, Khan A, Jalal F, Khan M, Khan H, et al. (2017): Dry Matter Partitioning and Harvest Index of Maize Crop as Influenced by Integration of Sheep Manure and Urea Fertilizer. Adv Crop Sci Tech 5: 276. doi: 10.4172/2329- 8863.1000276.

[45] Almaz M G. Halim R.A., Yusoff M.M. and Wahid S.A. (2017): Effect of incorporation of crop residue and inorganic fertilizer on yield and grain quality of maize. Indian J. Agric. Res., 51(6) 2017: 574-579. DOI: 10.18805/IJARe.A-264.