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Assessing mechanized, conservation, and small-scale tillage impacts on *Alexander wander* wheat performance in Bamenda, Cameroon

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ABSTRACT

Tillage practices constitute the major initial applications of farm power and machinery during crop cultivation. They comprise all soil-related manipulations aimed at preparing a good seedbed for appropriate crop growth. In order to improve crop yields while enabling sustainable soils, tillage practices executed during crop production in a particular region need to be assessed. The aim of this study was to investigate the impacts of tillage practices on *Alexander wander* wheat growth, and yield in Bamenda, Cameroon. An experiment was conducted during the cropping seasons of 2023 and 2024 at the research farm of the College of Technology of the University of Bamenda, Cameroon laid out in a randomized complete block design comprising five tillage treatments namely; mechanized tillage (disc ploughing followed by disc harrowing), conservation tillage (no-tillage, and strip tillage), and small-scale tillage (burning in ridges ("Ankara"), and traditional ridge tillage). Disc ploughing was conducted using a 3-disc standard right-handed disc plough followed by disc harrowing using an offset disc harrow. Tillage significantly influenced wheat performance (growth parameters, and yield attributes) during both the 2023, and 2024 cropping seasons. Ankara produced the best wheat performance followed by traditional ridge tillage. Disc ploughing followed by disc harrowing came third, while no-tillage, and strip-tillage practices produced the poorest wheat growth parameters, and yield attributes during both years. Thus, small-scale tillage practices (Ankara and traditional ridge tillage) are recommended for *Alexander wander* wheat production in Bamenda, Cameroon followed by mechanized tillage (disc ploughing followed by disc harrowing).

Keywords: Farm power and machinery, Agricultural mechanization, Tillage, Sustainable soils, Wheat grain yield.

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Introduction

Wheat (*Triticum aestivum*) is a major staple food crop that is consumed globally, and serves as an important food security crop in the world (Tadesse *et al.*, 2019). It is an essential cereal crop cultivated worldwide, covering about 20% of global food demands (Atamanyuk *et al.*, 2023). Wheat produced at the global level is 95% bread wheat (Tadesse *et al.*, 2019). A total of 808.4 million tonnes of wheat were produced globally in 2022: 44% produced in Asia, followed by Europe (33.7%), Americas (15.2%), Africa (3.6%), and lastly Oceania (3.4%) (FAO, 2024). Cameroon's wheat production is low (Shillie *et al.*, 2022), averaging a total quantity of 602.84 tonnes under a total area harvested of 451 hectares in 2022 (FAO, 2024). Due to the low domestic wheat production and high demand, Cameroon highly depends on Ukraine, and Russia for wheat imports (World Food Programme, 2022). High dependence on wheat importation disfavors local wheat farming thereby reducing wheat farmer income, and personal income tax thus the need to prioritize and improve local production (Shillie *et al.*, 2022). Local wheat production can therefore be enhanced through the application of improved agronomic/cultural, and soil management practices such as tillage practices (Busari *et al.*, 2015; Ndavi and Jaleta, 2019).

Tillage practices constitute the major initial applications of farm power and machinery during crop cultivation, mainly manipulating the soil through mechanical methods with the use of implements (e.g. ploughs, and harrows) mounted on powered machinery such as tractors, or attached to draught animals, or by the use of manual tools such as hand hoes by humans (Bekele, 2020). Tillage operations aim at preparing a good seed bed that will ensure appropriate seed germination and crop growth (Nweke, 2018). Tillage operations thus have considerable impacts on crop growth, and yields (Nweke, 2018; Ray and Rai, 2018). These impacts vary from one agricultural zone to another, and from one crop to the other thus, a tillage practice known to be best for a particular crop can produce adverse influence on another (Nweke, 2018). Testing different tillage systems therefore determines the superiority of one tillage practice over the other thereby ensuring adequate crop growth and yield (Nweke, 2018), and soil productivity (Dayou *et al.*, 2017). Several tillage practices are being applied for crop cultivation in Bamenda, Cameroon and include: mechanized tillage (disc ploughing followed by disc harrowing), conservation tillage (no tillage, and strip tillage), and small-scale tillage (burning in ridges (also known as "Ankara'), and traditional ridge tillage) (Bongajum and Suinyuy, 2015; Kum *et al.*, 2021; Mbachan and Ngwabie, 2024; Ngu *et al.*, 2020; Robiglio *et al.*, 2010). Studies conducted to provide scientifically robust evidence to recommend improved tillage practices for wheat production in the region are required. The aim of this study was therefore to investigate the influence of tillage practices on *Alexander wander* wheat performance (growth parameters, and yield attributes) in Bamenda, Cameroon.

Materials and Methods

Description of the study site

Field experiments were carried out at the research farm of the College of Technology of the University of Bamenda, Bamenda, Cameroon (latitudes 5.45°N-9.9°N, and longitudes 9.13°E-11.13°E) (Mbibueh *et al.*, 2021), during 2023, and 2024 cropping seasons (commencing in March and ending in June of each year). The maximum rainfall amounts during the field studies were recorded in June of both years (850 mm in 2023, and 500 mm in 2024), and the minimum rainfall was 250 mm in March of 2023, and 160 mm in May of 2024. Total rainfall amounts during the experiment were 1950 mm in 2023, and 1310 mm in 2024. Also, the mean daily temperatures were 22°C and 22.3°C, generally ranging between 17°C to 30°C, and 16°C to 30°C in 2023 and 2024, respectively (Department of National Meteorology, Ministry of Transport, Yaounde, Cameroon). The soil texture was classified as clay loam. The pH (H_2O) of the soil as defined by (Flynn, 2015) was slightly acidic. Also, the soil contained very high soil organic matter content, with a sufficient percentage of nitrogen, total phosphorus, potassium, magnesium, and calcium (Flynn, 2015). The soil had high soil organic carbon implying a high CEC (Magha *et al.*, 2021) (Table 1).

Table 1. Soil physio-chemical properties measured at the study site.

Soil property	Soil depth	
	0 – 15 cm	15 – 30 cm
Clay (%)	29.5	30.0
Sand (%)	40.5	41.0
Silt (%)	30.0	29.0
pH	6.4	6.4
Organic carbon (%)	5.7	4.5
Organic matter (%)	9.9	7.7
Total Nitrogen (%)	0.09	0.07
Ca (cmol kg^{-1})	2.6	1.9
Mg (cmol kg^{-1})	1.7	1.1
K (cmol kg^{-1})	2.5	3.2
CEC (cmol kg^{-1})	14.8	13.3
Available P (mg kg^{-1})	29.9	23.2

Experimental design and treatments

The experimental design utilized for the field experiment was a randomized complete block design consisting of five different tillage treatments namely; disc ploughing followed by disc harrowing (mechanized tillage practice), no tillage, and strip tillage (conservation tillage practices), as well as burning in ridges ("Ankara"), and traditional ridge tillage (small-scale tillage practices). The treatments were replicated thrice in plot sizes of 5 m x 5 m (25 m^2). Disc ploughing was conducted using a 3-disc standard right-handed disc plough followed by disc harrowing using an offset disc harrow mounted to the SONALIKA model tractor. At least 30% of the soil surface was left covered with crop residues in the no tillage and strip tillage plots. The non-residual herbicide glyphosate was sprayed two weeks prior to sowing on the no tillage plots after slashing (Schillinger and Wuest, 2014) to kill the weeds. The chemical herbicide was mixed with water and sprayed at an application rate of 4 L ha^{-1} using a sprayer load of 40 ml Glyphosate (Round-up) in 15 L knapsack sprayer. Dried vegetation was gathered into heaps and arranged as ridges on each burning in ridges plot, and soil was carried from the furrows using the traditional hand hoe and placed inverted on it leaving little side openings where the fire was lit for the burning of the vegetation (Kometa and Kang, 2017; Mbachan and Ngwabie, 2024; Robiglio *et al.*, 2010). The traditional tillage treatment was applied in two parts; the initial part whereby the slashed vegetation was gathered into ridges and soil was lightly carried from the furrows using the hand hoe and placed inverted on the ridges, then left for some weeks for the vegetation to decompose under the soil, and the final part which involved collecting enough soil from the furrows and thoroughly covering the initially lightly covered ridge to enable a better seedbed preparation and weed control (Mbachan and Ngwabie, 2024).

Wheat seeds of the *Alexander wander* species (a well-tested and highly adopted wheat species in Bamenda) were obtained from the Department of Crop Production Technology of the University of Bamenda, Cameroon and sowed at an optimum seeding rate of 500 seeds per square meter (Wozniak and Rachon, 2020), and a sowing depth of 2.5 cm using a manual dibbler (Reagan *et al.*, 2018). Intercrop, and inter-row planting distance was 25 cm (Buck and Keys, 2019). Weeds were controlled in three weeding sessions applying two different methods; the chemical herbicide method on the no tillage plots using Glyphosate mixed with water and sprayed at an application rate of 4 L ha^{-1}, and the manual hand hoe weeding method for the rest of the tillage plots.

Data collection

Growth parameters were determined from ten randomly selected plants per plot. Plant height was measured from the base of the soil to the tip of the epical leaves (Musa *et al.*, 2020) using a measuring tape (Shahwani *et al.*, 2014). The number of leaves per plant was counted using visual counts (Musa *et al.*, 2020). The length and width of the broadest and widest wheat leaf were measured by means of a meter tape. The leaf area was then determined according to the model developed by Chanda and Singh (2002) for the estimation of wheat leaf area given by:

$$Leaf\ area\ of\ wheat\ (cm^2) = 0.75\ x\ \text{length of wheat leaf (cm)}\ x\ \text{width of wheat leaf (cm)}$$

The yield parameters were also determined at harvest. The number of spikes (heads) was counted, the spike length measured using a meter rule, the number of spikes (heads) of the wheat plants in one foot (30.48 cm) per plot was counted, and the seeds in a spike threshed and counted (Shahwani *et al.*, 2014). Equally, 1000 seeds threshed per plot were weighed (Shahwani *et al.*, 2014) using an electronic balance to obtain the 1000 seed weight or seed index, and the grain yield (in t ha^{-1}) was determined using the model applied in estimating wheat yield developed by Clay and Carlson (2019) given as:

$$Wheat\ yield\ (t\ ha^{-1}) = \frac{\text{heads}}{\text{ft row x (row width in inches) x } {}^{1\ \text{ft}}/_{12\ \text{inches}}}\ \text{x}\ \frac{\text{number of seeds}}{\text{head}}\ \text{x}\ \frac{0.5445}{\text{row (inches)}}\ \text{x}\ 0.0673$$

Data analysis

Growth and yield data collected were analyzed using the Minitab Statistical Software 22 following the One-Way ANOVA procedure for Randomized Complete Block Design. Significant differences ($P<0.05$) between tillage treatments were determined using the Tukey Pairwise Comparisons (Turkey Simultaneous Tests for Differences of Means).

Results and Discussion

Influence of tillage practice on Alexander wander wheat growth parameters

Influence of tillage practice on plant height

Figure 1 and Figure 2 present the influence of tillage practice on *Alexander wander* wheat plant height during the cropping seasons of 2023, and 2024, respectively.

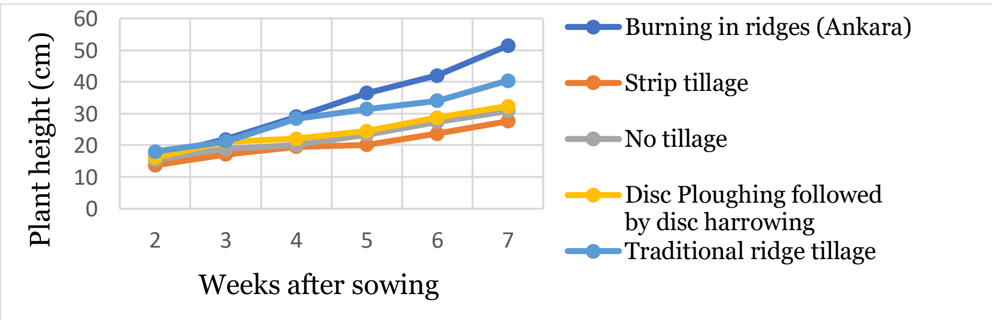

Fig. 1. Influence of tillage practice on *Alexander wander* wheat plant height in the 2023 cropping season.

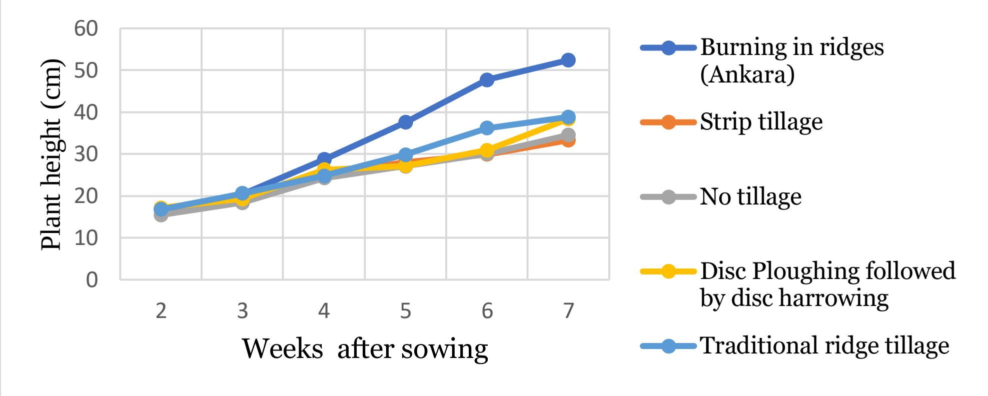

Fig. 2. Influence of tillage practice on *Alexander wander* wheat plant height in the 2024 cropping season.

At seven weeks after sowing, burning in ridges produced the mean tallest plants while the strip tillage produced the shortest plants during both years (Fig. 1 and Fig 2). Tillage influence on plant height for both the 2023 and 2024 crop growing seasons was of the order: Ankara > traditional ridge tillage > disc ploughing followed by disc harrowing > no-tillage > strip tillage. The tallest plants in the Ankara tillage treatment could be attributed to the production of powder ash due to the burning of vegetation (grasses and shrubs) underneath the soil leading to increased soil fertility (Abdulraheem, 2020; Bongajum and Suinyuy, 2015; Kometa and Kang, 2017). This study aligns with Ochecova *et al.* (2014) who reported increased growth of wheat plants due to the incorporation of biomass ash into the soil in the Czech Republic. Ash significantly increases soil nutrients such as potassium and phosphorus which are beneficial to plants thereby enhancing their growth (Ochecova *et al.*, 2014). Potassium activates at least sixty enzymes involved in plant growth (Prajapati and Moti, 2012), while phosphorus enhances metabolic processes which enable better growth (Malhotra *et al.*, 2018).

Influence of tillage practice on stem girth

As shown in Figure 3 and Figure 4, tillage produced mean bigger stem girths in 2023 than in 2024. During both years, burning in ridges produced the mean biggest stem girth followed by traditional ridge tillage, but both were statistically the same. Strip tillage on the other hand produced the smallest wheat stem girth throughout 2023 (Fig. 3), and from the fifth to the seventh week after sowing in 2024 (Fig. 4). The biggest stem girth in Ankara could be attributed to biomass burning which releases high amounts of phosphorus into the soil in a readily available form for crop absorption (Abdulraheem, 2020). Phosphorus according to Malhotra *et al.* (2018) stimulates and enhances stem strength, enlargement and growth.

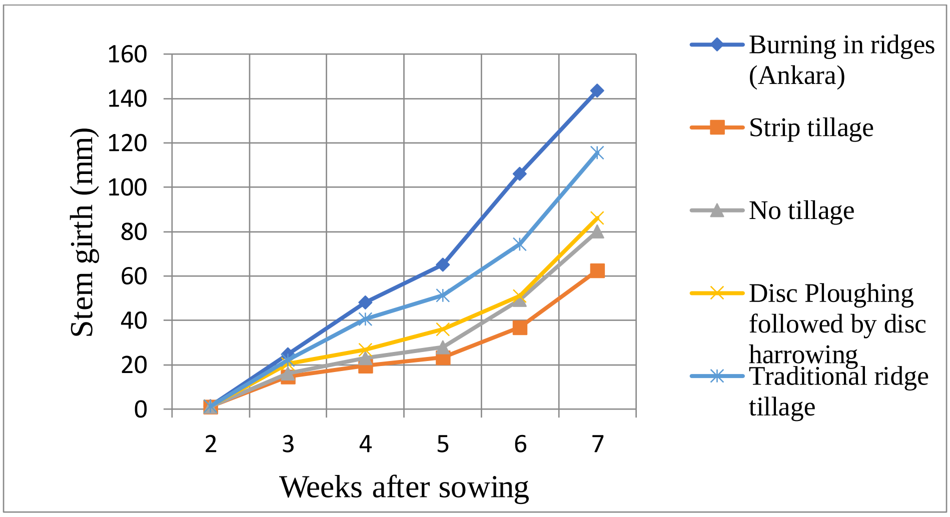

Fig. 3. Influence of tillage practice on the stem girth of *Alexander wander* wheat in the 2023 cropping season.

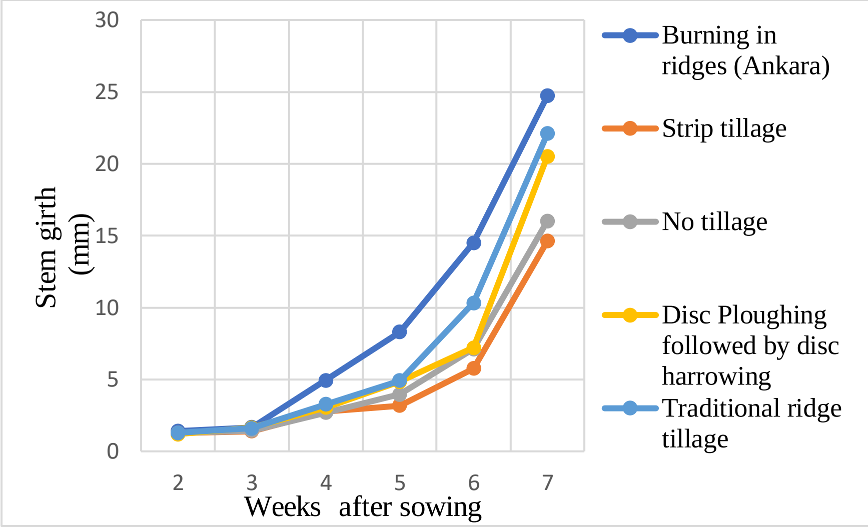

Fig. 4. Influence of tillage practice on the stem girth of *Alexander wander* wheat in the 2024 cropping season.

Influence of tillage practice on leaf area

Burning in ridges was significantly ($P<0.05$) higher than the other four tillage treatments at seven weeks after sowing, producing the broadest leaves during both years (33.33 cm² in 2023, and 29.10 cm² in 2024). On the other hand, strip tillage produced the smallest leaves from the second to the seventh week after sowing in 2023, and no-tillage produced the smallest leaves in 2024 except at the sixth and seventh weeks after sowing (Fig. 5 and Fig. 6).

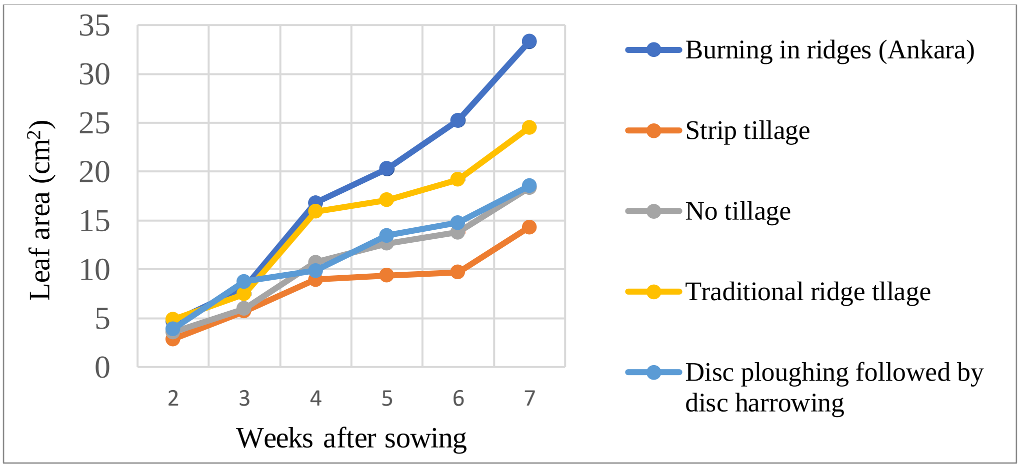

Fig. 5. Influence of tillage practice on *Alexander wander* wheat leaf area in the 2023 cropping season.

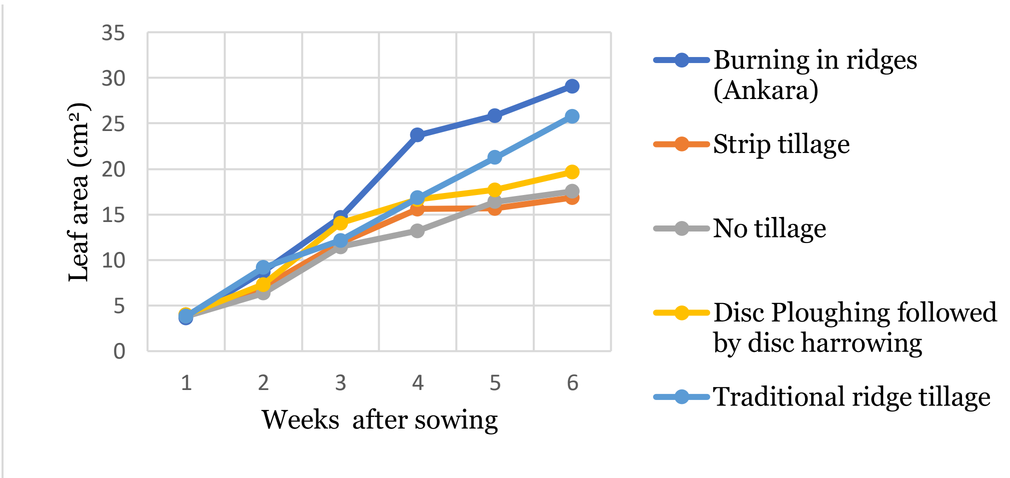

Fig. 6. Influence of tillage practice on *Alexander wander* wheat leaf area in the 2024 cropping season.

Broader leaves such as in the Ankara and traditional ridge tillage practices enable higher chlorophyll content, unit area exposure of the leaf to sunlight, and the efficiency of photosynthesis (Mathan *et al.*, 2016), than the strip tillage and no-tillage practices.

Influence of tillage on Alexander wander wheat yield attributes

Influence of tillage on spike length

The length of a wheat spike contributes significantly to grain yield per unit area (Shahwani *et al.*, 2014). In 2023, Ankara produced significantly ($P<0.05$) longer spikes (11.82 cm) than disc ploughing followed by disc harrowing, no-tillage, and strip tillage. In 2024, disc ploughing followed by disc harrowing rather produced the mean longest spikes (12.97 cm) while no tillage produced the mean shortest spikes (9.11 cm) (Table 2). This agrees with Gholami *et al.* (2014) who obtained the longest spike lengths in moldboard ploughing and the shortest in no-tillage. Disc ploughing breaks and loosens the soil, reducing soil bulk density, and increasing total porosity, and moisture content, while no tillage keeps the soil undisturbed, increasing soil bulk density, and reducing total porosity (Aikins and Afuakwa, 2012).

Influence of tillage on the number of seeds per spike

The number of seeds per spike makes up the most important factor that determines grain weight per plant (Shahwani *et al.*, 2014). In both years, burning in ridges resulted in a significantly ($P<0.05$) higher number of seeds per spike (22.67 in 2023, and 37.80 in 2024) than the other three tillage practices (no-tillage, disc ploughing followed by disc harrowing, and strip tillage), but was statistically the same with traditional ridge tillage (Table 2). Phosphorus is an important macronutrient that stimulates flowering and seed formation (Malhotra· *et al.*, 2018), thus its release through vegetation burning could have led to the increase in the number of seeds per plant in Ankara. Also, the decomposition of grasses covered underneath the soil could contribute to moisture retention (Coulibaly *et al.*, 2020) which aided in second-highest number of seeds per spike in traditional ridge tillage. The lowest mean number of seeds per spike was obtained under no-tillage. This aligns with Gholami *et al.* (2014) who recorded the lowest wheat number of seeds per spike in the no-tillage practice in Hakim Abad Village, Northern Khorasan Razavi province.

Influence of tillage on 1000 seed weight

The grain index or 1000 seed weight is an important parameter used to assess grain quality (Shahwani *et al.*, 2014). Ankara produced significantly ($P<0.05$) higher 1000 seed weight (42.33 g) compared to the other tillage practices in 2023, except in 2024 where it was statistically the same with traditional ridge tillage. Strip tillage on the other hand produced the smallest grain index during both years (Table 2). High amounts of phosphorus and potassium available in the soil due to the ash produced from burning vegetation (Abdulraheem, 2020) improved grain quality in Ankara (Malhotra *et al.*, 2018; Prajapati and Moti, 2012).

Influence of tillage on grain yield (t ha^{-1})

At harvest in 2023, Ankara produced significantly ($P<0.05$) higher grain yield (94.21 t ha^{-1}) than the rest of the tillage practices. In 2024, Ankara and traditional ridge produced the highest, and second-highest grain yield (52.6 t ha^{-1} and 23.46 t ha^{-1}) respectively (Table 2). Increased grain yields (t ha^{-1}) in Ankara is as a result of the potassium released from plant materials during burning which enables starch and protein synthesis, and increased yields (Prajapati and Moti, 2012). Strip tillage, and no-tillage gave the mean lowest grain yields of 29.67 t ha^{-1} and 3.78 t ha^{-1} in 2023 and 2024 receptively (Table 2), but both were statistically the same with disc ploughing followed by disc harrowing. These results agree with (Pisante and Basso, 2000) who observed no significant differences between mechanized tillage and conservation tillage practices for the grain yield (t ha^{-1}) of wheat in Southern Italy. They on the other hand align with (Gholami *et al.*, 2014) who recorded the highest wheat grain yield in conventional tillage and the lowest in no-tillage.

Table 2. Influence of tillage practice on *Alexander wander* wheat number of spikes per plant, spike length, number of seeds per spike, 1000 seed weight (grain index), and grain yield (t ha^{-1}) at harvest during the 2023 and 2024 cropping seasons.

Tillage practice	Number of spikes per plant		Spike length (cm)		Number of seeds per spike		1000 seed weight (g)		Grain yields (t ha^{-1})	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Disc ploughing followed by disc harrowing	13.33± 2.08	7.20± 1.91	10.00± 0.45	12.97± 1.53	16.33± 2.53	21.60± 4.69	36.43± 2.01	29.67± 1.16	30.48± 7.99	11.65± 3.16
Strip tillage	09.67± 2.52	5.67± 3.25	09.79± 0.27	10.73± 3.38	13.67± 0.58	16.27± 3.52	34.70± 1.31	27.17± 2.03	29.67± 12.45	7.86± 2.55
No tillage	13.67± 6.66	4.60± 2.31	10.15± 0.88	09.11± 3.72	16.68± 1.53	05.72± 2.14	37.24± 1.47	30.10± 0.30	40.27± 7.14	3.76± 2.36
Burning in ridges	34.33± 10.60	13.27± 4.79	11.82± 0.16	11.93± 2.20	22.67± 1.53	37.80± 4.50	42.33± 0.59	37.16± 1.79	94.21± 12.42	52.6± 22.9
Traditional ridge tillage	19.33± 7.09	9.60± 1.38	11.04± 0.81	11.07± 2.72	20.33± 2.08	31.07± 0.83	39.02± 1.20	34.73± 5.00	52.02± 7.14	35.46± 9.74

Conclusion

This study demonstrated that tillage significantly affected *Alexander wander* wheat performance (growth parameters and yield attributes) during both the 2023, and 2024 crop-growing seasons. The Ankara tillage practice produced the best growth parameters in terms of tallest plants, biggest stem girths, highest number of leaves and tillers per plant, broadest wheat leaves, as well as best wheat yield attributes; highest number of spikes per plant, longest spike length, highest number of seeds per spike, highest 1000 seed weight, and grain yield (t ha^{-1}). Traditional ridge tillage followed producing second best wheat growth parameters and yield attributes while disc ploughing followed by disc harrowing came third. Strip tillage and no tillage produced the poorest wheat performance in terms of growth parameters and yield attributes. Ankara tillage and traditional ridge tillage practices with the best performances during both years are thus recommended for *Alexander wander* wheat production in the Bamenda, Cameroon followed by disc ploughing followed by disc harrowing. In order to reduce the intensity of burning vegetation underneath the soil which may be detrimental to soil health and sustainable farming, it is recommended for wheat farmers to improve on applying the Ankara tillage practice by incorporating already prepared powder ash into the soil.

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