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Influence of different organic mulches on growth, yield and oil content of maize (*Zea mays* L.) hybrids and soil physical properties

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ABSTRACT

Sustainable agricultural practices are significantly addressing the challenges posed by climate change and soil degradation, which threaten crop productivity and food security. Organic mulching is the practice of applying natural materials on soil to improve moisture retention, regulate temperature and enhance crop productivity. Hence, a two year (2019 and 2020) field study was executed to investigate the effects of various organic mulches on yield, quaility and soil physical properties of maize hybrids. A field experiment was conducted with four different organic mulching treatments i.e. (M1) sawdust (5 Mg ha^{-1}), (M2) sugarcane bagasse (5 Mg ha^{-1}), (M3) wheat straw (10 Mg ha^{-1}), and (M4) grass clippings (10 Mg ha^{-1}). In this study two maize hybrids i.e. (H1) YH-1898 and (H2) DK-6317 were tested gainst afroemtioned attributes. The findings revealed that sugarcane bagasse mulch significantly enhanced yield and yield-related attributes, including plant height, cob length, cob girth, number of grains per cob, number of grain rows per cob, 1000-grain weight, grain yield and harvest index as compared to other mulching materials. Additionally, the quality parameters such as protein, starch and oil content were highest in the sugarcane bagasse treatment, followed by sawdust mulch. In terms of soil health, sugarcane bagasse also exhibited the highest values for electrical conductivity (EC), total soil porosity and organic matter content compared to other treatmens. These results highlight the effectiveness of sugarcane bagasse as an optimal organic mulch for sustainable maize production.

Keywords: maize, organic mulch, soil properties, quality, yield attributes.

INTRODUCTION

Maize is the 'Queen of Cereals' among cultivated cereals globally and is ranked as 3rd largest crop based on the area under its cultivation and production after wheat, and rice. While, in Pakistan, it is 4th largest cultivated crop after wheat, rice, and cotton, respectively (Hussain et al., 2022). Globally, it is mainly preferred to be cultivated to obtain quality grains and highly palatable forage. The significant contribution of Maize to Pakistan's GDP is evident from the (Pakistan Economic Survey; 2022-23) with its 0.7 percent share and 3.0 percent value addition in agriculture.

Maize production in Pakistan faces numerous yield-limiting challenges including soil degradation, water scarcity, and climate change. Simon et al. (2023) concluded that climate change phenomena are characterized by increased temperature levels, variation in precipitation distribution and patterns, and frequent extreme weather events, affecting maize crops adversly. Additionally, another study by (Sajjad et al. 2024) found that soil degradation accelerates water stress and reduces the fertility status of agricultural land, further hindering maize production. These challenges are to be addressed with sustainable agronomic crop management practices, including efficient water management, mulching, and innovative adaptation approaches to ensure the resilience and productivity of maize cultivation systems.

In agriculture, mulches are defined by Chalker-Scott (2007) as the materials that are applied to the soil surface, instead of materials that are incorporated into the soil profile. Further, mulch is a layer of material(s) that serves as a covering and protective source to the soil surface. Additionally, a review by El-Beltagi et al. (2022) concluded that depending on the type of mulch material used, mulching preserves soil water, reduce soil temperature and consequently promotes seedling establishment and increases the seedling survival under extreme conditions mainly by reducing the soil surface exposure to direct solar radiation. Organic mulches can also improve physical, chemical and biological properties of soil, as they decompose and release nutrients to the soil (Ampofo, 2018).

Organic mulches offer a variety of advantages in crop fields, ranging from moisture retention to weed control, temperature regulation, and soil fertility improvement. An investigation by (Zhang et al. 2023) has confirmed that organic mulching materials can improve soil temperature retention, maintain moisture levels, water use efficiency, and crop yield. Furthermore, organic mulches help reduce evaporation, suppress weed populations, and retain soil moisture ultimately benefiting crop growth, development, and yield under water-scarce conditions (Sajid et al., 2023).

The role of soil physical properties such as structure, texture, temperature, and moisture content is critical in normal plant growth and crop yield. The findings of (Sainju et al., 2022) are evident that these properties influence the availability of water and nutrients to plants, root development, and overall soil health indicators, and significantly affecting crop productivity. It has been concluded by Yang et al. 2022 that soil texture affects water retention and drainage, so it's crucial for normal root growth and nutrient uptake. On the other hand, for plants to grow, aeration and root penetration are influenced by the soil's structure. Plant hydration and nutrient transport within the soil are directly linked to the soil moisture content availability. Temperature influences microbial activity and nutrient availability, so both are critical for plant metabolism and growth (Sainju et al., 2022).

Organic mulches play a significant role in influencing various soil physical properties. Recent research indicates that organic mulches lead to rapid changes in soil's most important chemical property known as soil pH while affecting hydraulic properties gradually (Fer et al., 2022). Different organic mulch varieties have been studied for their impact on soil moisture and crop growth, showing that mulches can improve soil moisture and weaken surface runoff (Zhang et al., 2023). Additionally, organic mulches contribute to increased water infiltration, evaporation control, and weed management, improving soil organic matter maintenance and physical conditions (Khalid et al., 2022). Studies have shown that organic amendments like organic fertilizers and mulches can reduce soil bulk density, increase total porosity, and enhance water-filled pores, ultimately improving soil productivity (Akinwumi et al., 2022). Overall, organic mulches positively influence soil physical properties by enhancing soil aggregation, reducing water evaporation, and improving structural stability and porosity (Mubaraka et al., 2022).

The research study was conducted to assess the impact of different organic mulches on the growth and yield of maize hybrids and to evaluate the effects of these mulches on various soil physical properties.

MATERIALS AND METHODS

Experimental details

The two-year experimental study was performed during spring 2019 and 2020 at the Agronomic Research Area, University of Agriculture, Faisalabad. According to the recent agroecological zones classification of Punjab, the selected experimental site is dry semi-arid and the soil type is sandy clay loam. The experiment was set up using a Randomized Complete Block Design (RCBD) under split plot arrangements having three replications. Organic mulches mulching materials i.e. (M1) sawdust (5 Mg ha^{-1}), (M2) sugarcane bagasse (5 Mg ha^{-1}), (M3) wheat straw (10 Mg ha^{-1}) and (M4) grass clipping (10 Mg ha^{-1}) were kept in main plot while maize hybrids i.e. (H1) YH-1898 and (H2) DK-6317 allocated to sub plot.

Before conducting the proposed research trial soil samples were collected from the target site at depths of 1–15 cm and 15–30 cm and then examined through an analytical laboratory analysis for physical and chemical properties after air-drying and crushing. The proportions of soil particles such as sand, silt, and clay were estimated by following the Bouyoucos hydrometer method by taking 1% sodium hexametaphosphate as a scattering agent (Moodie et al., 1959). In addition, numerous soil chemical properties have been analyzed using techniques established by Homer and Pratt (1961). The agro meteorological data of weather during research from March-June 2019 and 2020 given in Figure 1.

Crop sowing and management

Two maize hybrids were sown manually on 8th March 2019 and 2020 on ridges by keeping 60 cm (row to row) and 25 cm (plant to plant) distances and seed rate at 25 kg ha-1 was used. The specified amount of plant-based mulching material was applied on soil according to the treatments. All agronomic management practices were applied to whole treatments including thinning, crop nutrition, irrigation, plant protection measures, harvesting, threshing, shelling and sample collection.

Determination of crop yield attributes

To estimate numerous crop yield-related parameters, ten plants as samples were harvested as a destructive sample technique. All sample plants were subjected to the mechanical threshing process to find out the yield of each plot in kg and transformed to the units of t ha^{-1}.

Plant height in centimetre (cm) was measured through the measuring tape by selecting five demonstrative plants randomly from each treatment plot by taking readings from the ground surface to the topmost plant part. Similarly, the sampling technique utilized for plant height was followed to determine the number of cobs per maize plant and calculate the average for each treatment. In addition, maize cob length (cm) and cob diameter (cm) were measured by taking five samples randomly from each treatment with measuring tape and Vernier caliper and the average was calculated, respectively.

The number of grains per row and the number of grain rows per cob were counted by selecting five cobs randomly from each replication plot representing a particular treatment respectively after harvesting the maize crop. Moreover, 1000-grain weight (g) was calculated by taking three representative samples from each treatment after sun drying. After that, each collected sample was oven-dried at 70 ± 5°C, and a digital weighing balance was used to measure weight and finally estimate the mean value. The grain yield (t ha^{-1}) was determined by separating the grains from sun-dried cobs using a maize Sheller and grain yield measured in kg which was transformed into t ha^{-1}.

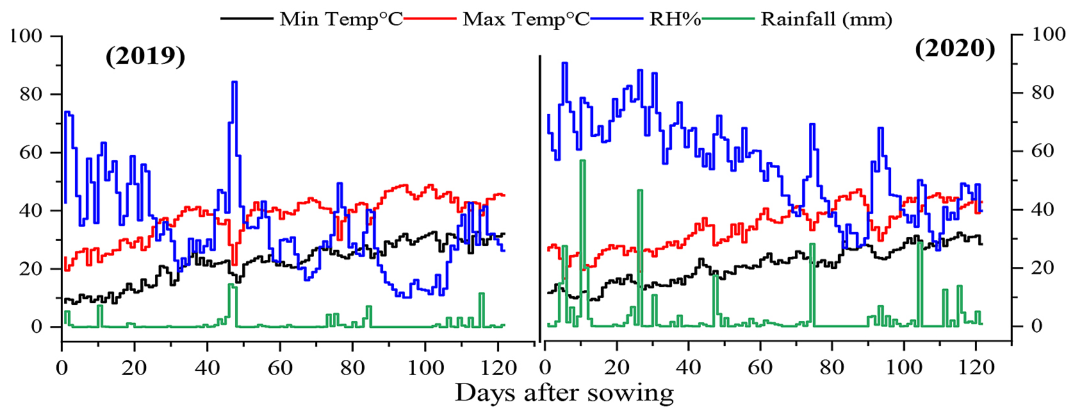

Figure 1. Weather attributes i.e. maximum and minimum temperature, relative humidity and rainfall during growing seasons of 2019–20 and 2020–21

Calculation of biological yield, harvest index, and shelling (%)

Maize stalks and cobs were weighed using a digital weighing balance to measure the biological yield from each treatment representative plot and converted into units of t ha-1. However, harvest index is the proportion of economic yield over biological yield. It is estimated using the following formula:

$$\textit{Harvesting index}\ (\%) = \textit{Economic yield} / \textit{Biological yield} \times 100 \quad (1)$$

Quantification of grains nutrient profile

The grain nutrient profile was figured out by the procedure prescribed by the AOAC (1990). That investigation followed a series of steps comprising a uniform size sample of 100 g grain extracted from each replication of treatment, sun-dried, grinded and finally sieved to subjected for quality analysis including protein content (%), oil content (%), and starch content (%).

Protein content (%)

To determine the nitrogen percentage Kjeldahl method was used as described by (AOCA, 2006) and then crude protein %age was measured by multiplying the percentage of total nitrogen with 6.25. First of all, digestion process was done to determine the nitrogen percentage from sample.

Took 1 g of the dried sample, added 5 g digestion mixture that was consisted of 90 parts K_2SO_4 (to raise the boiling points), three parts of FeSO4 and seven parts of $CuSO_4$ (act as catalyst) both digestion mixture and feed sample were put into digestion flask (500 mL) and added 25-30 commercial H_2SO_4 and heated till colorless content appeared. After digestion, digested content transferred into 250 mL volumetric flask and added distil water to make 250 mL volume. Took 10 mL volume solution from volumetric flask and added 10 mL 4% NaOH solution, whereas in another flask took 10 mL boric acid and added one drop of methyl red as an indicator, heated till the fumes of ammonia was appeared and NH3 gas is trapped by 4% H_3BO_4. The end point of the solution was yellow after this and waited for two minutes and removes the flask containing boric acid and then removes the steam unit.

Titrated the boric acid solution with N/10 H_2SO_4 till golden yellow color appeared and recorded the volume of acid used.

$$N\ (\%) = \frac{\text{Volume of}\ \frac{\text{N}}{10}\ H2SO4 \times vol.of\ sample\ dilution}{\text{Wt. of sample} \times \text{volume of solution used (10ml)}} \times 100 \quad (2)$$

$$\textit{Protein contents} = N \times 6.25$$

Oil's contents (%)

The Soxhlet method (Low, 1990) was employed to measure oil content in maize grain samples extracted after taking several primary samples from each particular treatment later mixed them well, and prepared a composite sample to run the desired analysis.

Starch contents (%)

The gluco-analysis procedure attempted to estimate the percentage of starch content in maize grains. To achieve this, first sample is oven dried to constant weight and then grinded to powder and later the procedure is run to obtain starch content percent.

Evaluation of soil phyio-chemical properties

Soil pH

An important soil chemical property is pH; determined by using deionized water in a beaker to prepare a saturated soil paste (400 g). Then soil pH was recorded using a standardized pH meter at 7.01 and 9.20 pH buffer solution. As the glistening appearance of soil-saturated paste appears, a representative pH meter reading was noted.

Electric conductivity (dsm^{-1})

Electrical conductivity (EC) is one of the significant soil chemical properties indicators; determined by measuring the electrical conductivity of saturated soil paste with a standardized HANNA HI-8033 EC meter at 0.01N KCL solution.

Soil's bulk density (Mg m^{-3})

Soil bulk density is one the important soil physical properties. The bulk density of the representative soil sample collected from the farm research area was estimated by following the (Blake and Hartge 1986) procedure. This accomplished by collecting the demonstrative soil samples at 0.08 depth with 0.05 diameter soil cores were collected.

$$B.D = \frac{Mass\ of\ Oven\ dry\ soil}{Vol.of\ soil} \quad (3)$$

Total soil porosity (m^3m^{-3})

The porosity of soil is the volume of space between the mineral particles of soil. It varies greatly from soil to soil because soil contains various soil particles with varying levels either loosely or densely packed.

Soil organic matter

0.5 g of soil sample was added to the beaker of 500 ml, and then potassium dichromate of 10 ml was included and mixed entirely. Concentrated sulfuric acid as 20 ml was included to mix the suspension in the beaker then permit the beaker material to stand for 30 minutes. After this, put in 200 ml deionized water, 100 ml concentrated orthophosphoric acid, and diphenyl-amine ether 10–15 drops as the indicator. It was titrated in contrast to the 0.05 M (Standard) Ferrous Ammonium Sulphate solution after cooling the entire mixture. It allowed the color of the mixture to convert from green to blue.

$$\%Oxidizable\ organic\ Carbon\ \left(\frac{w}{w}\right)$$

$$= \frac{ml\ used\ for\ blank\ reading\ - \\ -\ ml\ used\ for\ sample\%}{Soil\ Weight\ (g)} \times 0.3 \times \mathrm{M} \quad (6)$$

- Total organic carbon percentage = 1.334 percent organic carbon oxidation,
- Percentage of organic matter = 1.724 percent of total organic carbon,
- M – molarity of solution of ferrous sulphate as (0.5 M).

Statistical data analysis

Data were collected during the research study and statistically analyzed through Fisher's analysis of variance approach and compared treatment means by employing LSD (least significant difference) test at 5% probability level (Steel et al., 1997). Morover, graphical representation was made by using paired comparsion plot technique with help of OriginPro-2025 SR0 as well as correaltion anlaysis was done by employing tow tailed t test (df-2).

RESULTS

Yield components

Maize hybrids depicted a significant ($p \leq 0.05$) increase in plant height by the application of mulches in both year of 2019 and 2020 (Figure 2). Application of different mulches increased plant height in the range of 7–16% and 8–14% in YH–1898 and DK–6317, respectively as compared to control in 2019. Similar trend was observed in 2020 resulting 8–26% increase in plant height over control in both hybrids respectively. Application of grass clipping mulch showed moderate (8–15% increment as compared to control) efficiency that resulted less effective as compared to wheat straw and sawdust mulch in both years. Nonetheless, maximum plant height was observed with sugarcane bagasse mulch application that resulted in 25–28% and 23–27% increase in plant height in 2019 and 2020, respectively in both hybrids as compared to control. Maize delineated a significant ($p \leq 0.05$) increase in cob length by the application of mulches in 2019 and 2020 (Figure 2). Cob length was increased in the range of 3–26% in YH-1898 hybrid and 4–25% in DK-6317 hybrid over control by the application of different organic mulches in 2019. Parallel trend was observed in 2020 that resulted 5–25% increase in cob length as compared to control in both hybrids. Application of wheat straw mulch contribute 2–10% more cob length as compared to grass clipping and sawdust in both years. However, maximum cob length was observed in both hybrids by the sugarcane bagasse mulch application that resulted 37–50% and 33–57% increase as compared to control in 2019 and 2020, respectively. Maize demarcated a significant ($p \leq 0.05$) increase in cob girth by the application of different mulches in 2019 and 2020 (Figure 2). Application of different mulches on YH-1898 hybrid increased the cob girth in the rage of 42–69% and 45–50% in 2019 and 2020, respectively, while DK-6317 hybrid treated with different mulches resulted increased in cob girth in the range of 14–22% and 5–27% in 2019 and 2020, respectively. Mulch of grass clipping application performed average 6-8% less efficiency as compared to sawdust and wheat straw mulches in both years. Maximum cob girth was detected by the application of sugarcane bagasse that resulted 44–71% and 27–52% high in 2019 and 2020 respectively over control in both hybrids.

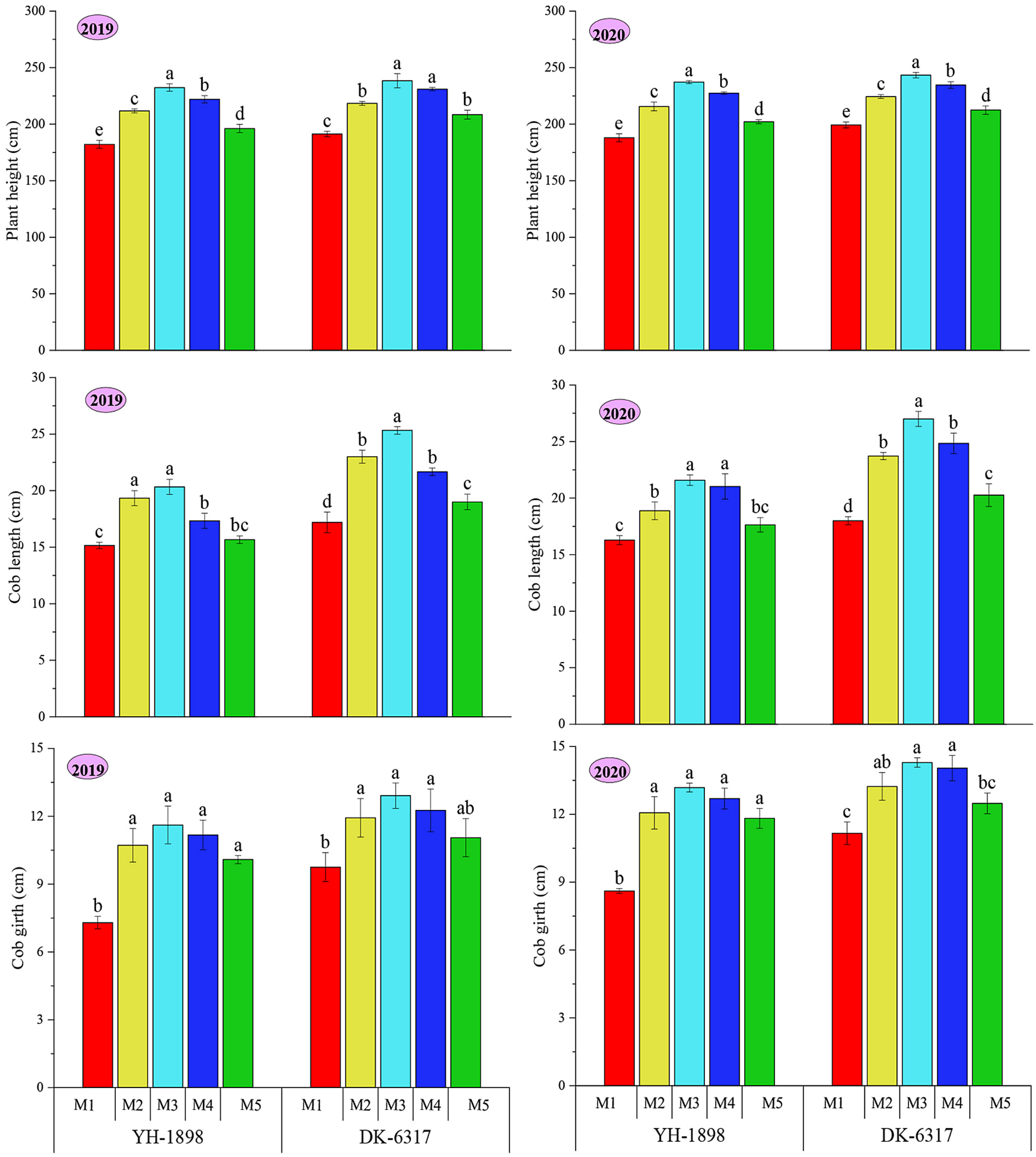

Figure 2. Effect of mulches on plant height (cm), cob length (cm) and cob girth (cm) of maize hybrids; similar letters mean non-significant ($P \leq 0.05$) differences which was calculated through LSD at 5% level of probability

Maize illustrated a significant ($p \leq 0.05$) increase in number of grains per cob by the application of different mulches in 2019 and 2020, respectively (Figure 3). Application of different mulches increase the number of grains per cob in the range of 1–1.2 and 1.1–1.2 times in YH-1898 and DK-6317 respectively as compared to control in 2019. Similar trend was observed in 2020 resulting 1.1–1.3 times increase in number of grains per cob over control in both hybrids, respectively. Wheat straw mulch was 1.02–1.05 more efficient as compared to sawdust and grass clipping mulch, respectively. However, sugarcane bagasse treatment shows highest number of grains per cob resulting in 1.21–1.25 and 1.21–1.29 times increase in 2019 and 2020, respectively in both hybrids as compared to control. Maize presented a significant ($p \leq 0.05$) increase in number of grain rows

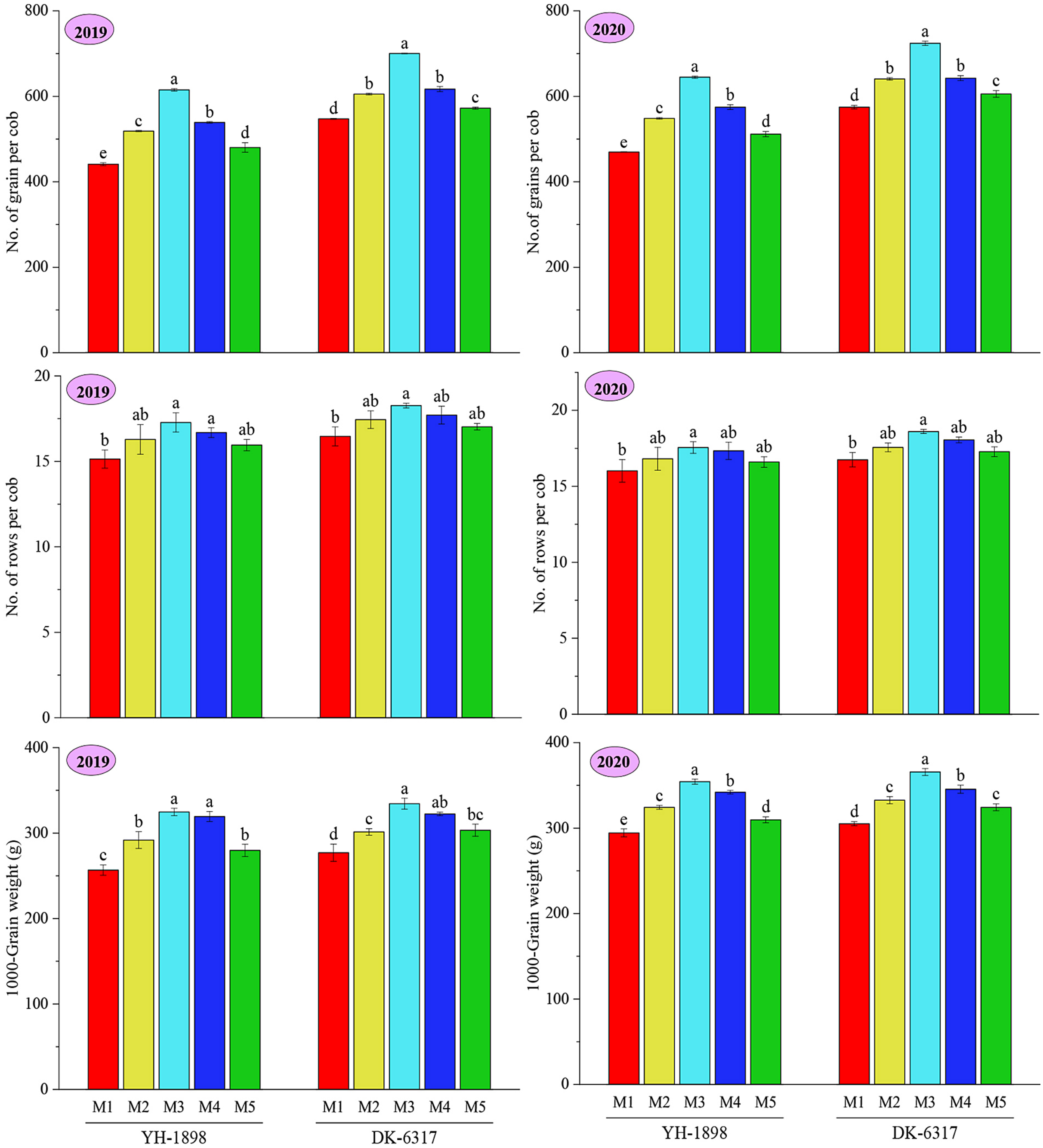

Figure 3. Effect of mulches on no. of grain per cob, no. of rows per cob and 1000-grain weight (g) of maize hybrids. Similar letters mean non-significant ($P \leq 0.05$) differences which was calculated through LSD at 5% level of probability

per cob by the application of mulches in 2019 and 2020 (Figure 3). Number of grain rows per cob was increased in the range of 1.05–1.13 times in YH-1898 hybrid and 1.05-1.10 in DK-6317 hybrid over control by the application of different organic mulches in 2019. Parallel trend was observed in 2020 that resulted average 1.03–1.09 times increase in number of grain rows per cob as compared to control in both hybrids. Application of sawdust mulch decreased by 1.06 times number of rows per cob as compared to sugarcanes bagasse but increase 1.08 times over control. Conversely, maximum number of grain rows per cob was observed in both hybrids by applying sugarcane bagasse mulch that resulted 1.14–1.8 times increase in 2019, and 1.07–1.11 times increase in 2020 over control. Maize determined a significant ($p \leq 0.05$) increase in weight of 1000-grain by the application of different mulches in 2019 and 2020 (Figure 3). Application of different mulches on YH-1898 hybrid increased the 1000-grain weight in the range of 1.24–1.26 and 1.05–1.20 in 2019 and 2020, respectively, while DK-6317 hybrid treated with different mulches resulted increase in 1000-grain weight in the range of 1.09–1.20 and 1.06–1.19 in 2019 and 2020, respectively. Mulch of grass clipping application performed average 1.04–1.14 times less efficiency as compared to sawdust and wheat straw mulches in both years. Maximum 1000-grain weight was observed by the application of sugarcane bagasse mulch that resulted 1.26–1.20 and 1.19–1.20 times more in 2019 and 2020 respectively as compared to control in both hybrids.

Application of different mulches significantly ($p \leq 0.05$) increased grain yield of maize in both hybrids in 2019 and 2020 (Figure 4). Grain yield was increased in the range of 18–50% and 17–45% in YH-1898 and DK-6317 hybrids respectively as compared to control in 2019. While in 2020, 14–50% and 18–43% increase in grain yield was observed as compared to control in both hybrids. Minimum grain yield was peoduced by mulching of grass clipping in both years and application of sugarcane bagasse resulted maximum grain yield (51–61% increment) as compared to control in both hybrids in 2019. Similar trend was spotted in 2020 that resulted 43–50% increase in grain yield over control in YH-1898 and DK-6317 hybrids, respectively. Both hybrids of maize showed significant ($p \leq 0.05$) increase in biological yield in 2019 and 2020 (Figure 4). Application of different mulches increased biological yield in the range of 22–45% and 12–30% as compared to control in 2019 and 2020, respectively in YH-1898 hybrid, while in DK-6317 hybrid, biological yield was increased in the range of 11–33% and 16–22% over control in both years, respectively. However, maximum biological yield was observed by the application of sugarcane bagasse subsequent 45% and 33% increase as compared to control in YH-1898 and DK-6317 hybrid, respectively in 2019 and 22–30% increase over control was observed in 2020 in both hybrids. Harvest index was significantly ($p \leq 0.05$) increased in both hybrids by the application of different mulches (Figure 4). In 2019, harvest index was increased in the range of 1–13% as compared to control in YH-1898 hybrid and 10–14% increase over control was observed in DK-6317 hybrid. Comparable trend was observed in 2020 resulting 4–22% and 4–20% increase over control in YH-1898 and DK-6317 hybrid respectively. However, maximum harvest index was seen when both hybrids were treated with sugarcane bagasse resulting average 14–22% more harvest index as compared to control in both years. Although the differences between the two maize hybrids were less pronounced than the effects of mulching treatments, YH-1898 generally exhibited slightly higher values for growth and yield parameters, including plant height, cob length, 1000-grain weight and grain yield, compared to DK-6317. Grain quality attributes such as protein and oil content were also marginally superior in YH-1898. These modest varietal differences likely reflect the similar genetic potential and maturity duration of the hybrids, as well as the dominant influence of organic mulches in enhancing crop performance. Nonetheless, the consistent trend favoring YH-1898 highlights its suitability for organic mulch-based cultivation systems.

Quality attributes

Maize depicted a significant ($p \leq 0.05$) increase in protein content by the application of mulches in 2019 and 2020 (Figure 5). Application of different mulches increased protein content in the range of 1.16–1.33 and 1.06–1.24 times in YH-1898 and DK-6317, respectively as compared to control in 2019. Similar trend was observed in 2020 resulting average 1.13–1.21 times increase in protein content over control in both hybrids, respectively. Application of grass clipping mulch showed moderate (1.10–1.15 times more as compared to control) efficiency that resulted less effective as compared to wheat straw and sawdust mulch in both years. Nonetheless, maximum protein content was observed by treating with sugarcane bagasse mulch that resulted 1.24–1.33 and 1.21–1.25 times increase in protein content in 2019 and 2020, respectively in both hybrids as compared to control. Maize depicted a significant ($p \leq 0.05$) increase in starch contents by the application of mulches in 2019 and 2020 (Figure 5). Starch content was increased in the range of 1.03–1.15 times in YH-1898 hybrid and 1.02–1.05 in DK-6317 hybrid over control by the application of different organic mulches in 2019. Parallel trend was observed in 2020 that resulted average 1.01–1.04 times increase in starch contents as compared to control in both hybrids. Application of sawdust mulch decreased

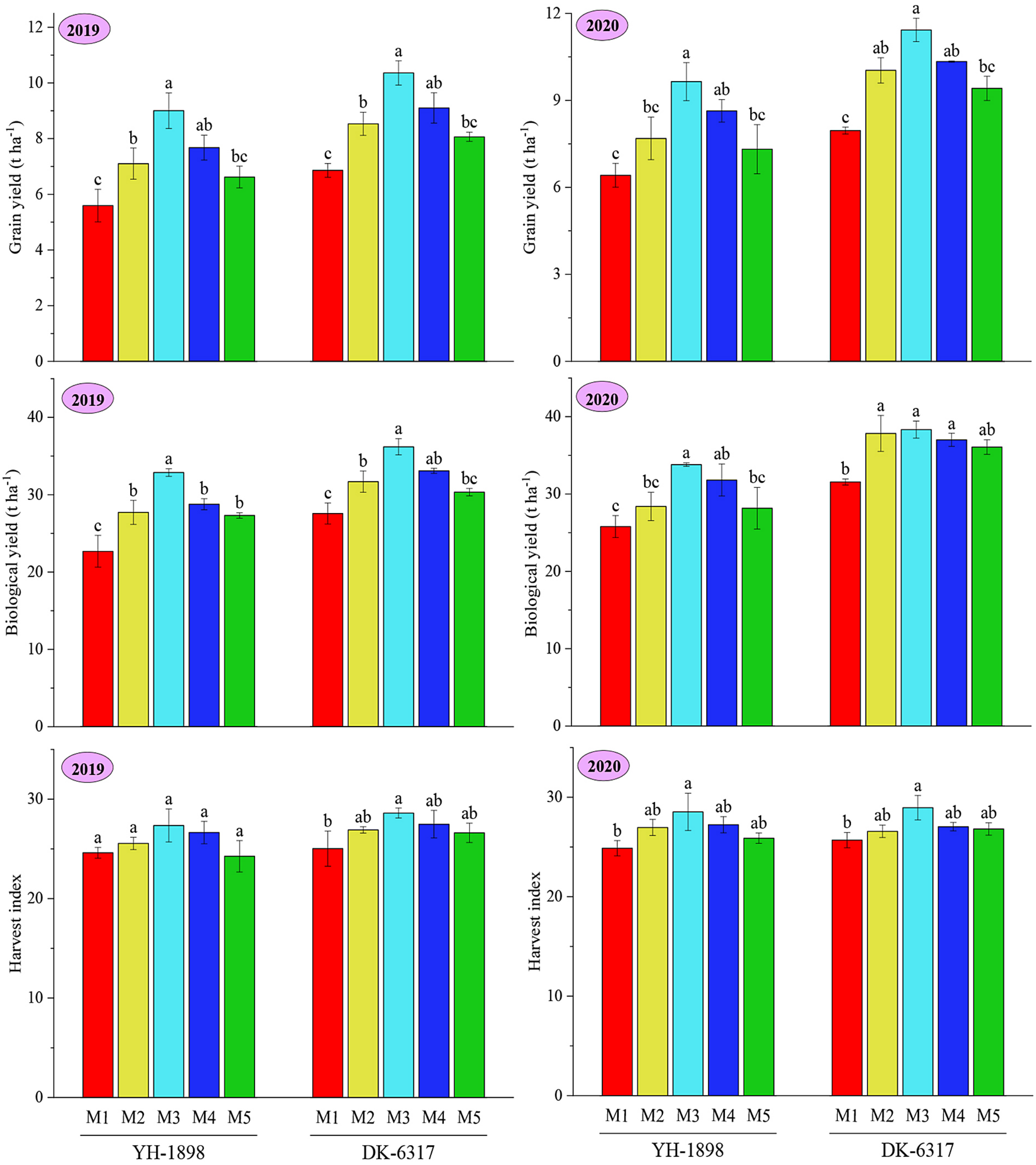

Figure 4. Effect of mulches on grain yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest indexof maize hybrids; similar letters mean non-significant ($P \leq 0.05$) differences which was calculated through LSD at 5% level of probability

1.02 times starch contents as compared to sugarcanes bagasse treatment but increase 1.05 times over control. Conversely, maximum starch contents were observed in both hybrids by the application of sugarcane bagasse mulch that resulted 1.04–1.05 times increase in 2019, and 1.04–1.06 times increase in 2020 over control. Maize presented a significant ($p \leq 0.05$) increase in oil contents by the application of mulches in 2019 and 2020 (Figure 5). Oil contents was increased in the range of 1.09–1.32 times in YH-1898 hybrid and 1.09–1.23 in DK-6317 hybrid over control by the application of different organic mulches in 2019. Parallel trend was observed in 2020 that resulted in average 1.14–1.23 times increase in oil contents as compared to control in both hybrids. Application of sawdust mulch decreased 1.14 times number of rows per cob as compared to sugarcanes bagasse application but increase 1.15 times over control. Conversely, maximum oil contents were observed in both hybrids by the application of sugarcane bagasse mulch that resulted 1.23–1.32 times increase in 2019, and 1.16–1.23-times increase in 2020 over control.

Soil attributes

Both hybrids of maize decreased soil pH when treated with different mulches (Table 1). In 2019, pH was decreased in the range of 1.00–1.01 by treating with organic mulches as compared to control in both hybrids. While pH was decreased in the range of average 1.01 in both hybrids in 2020 when treated with all mulches. Electrical conductivity was increased by treating with different mulches (Table 1). Sawdust and grass clipping application increased electrical conductivity in the range of 1.22–1.29 and 1.24–1.27 times in 2019 and 2020 respectively as compared to control in both hybrids. While maximum electrical conductivity was observed treatment sugarcane bagasse that resulted 1.51 time more as compared to control in 2019 and 1.54 more over control in 2020 in both hybrids. Application of mulches decreased soil bulk density as compared to control in 2019 in both hybrids (Table 1). Similar trend was observed in 2020 as grass clipping mulch decreased average 1.11 times bulk density as compared to control. While 1.16, 1.26, 1,17 times decreased in bulk density of soil was observed as compared to control in both years by the application of sawdust, sugarcane bagasse and wheat straw mulches respectively in both years. Total soil porosity was increased by the application of mulches in both hybrids (Table 1). Mulch of grass clipping increased 1.18 times total soil porosity over control but 1.06 time decreased as compared to sugarcane bagasse. Total soil porosity was increased when both hybrids was treated with sugarcane bagasse mulches resulting 1.3–1.5 times more as compared to control in both years. Application of organic mulches increased organic matter in soil in 2019 and 2020 (Table 1). Mulches of sawdust and grass clipping showed equal efficiency for enhance organic matter in soil in both years. Wheat straw mulches increased 1.12 times more organic matter as compared to control in 2019 in both hybrids. Similar trend was followed in 2020 resulted 1.11 time more organic matter as over control. While maximum output was seen when both hybrids are treated with sugarcane bagasse that resulted 1.16 and 1.25 times as compared to control in 2019 and 2020, respectively.

Correlation

A two-year correlation analysis (2019 and 2020) was conducted in order to assess the interaction between maize grain yield and various studied traits. The findings showed that during first year grain yield in a beneficial correlation with all traits e.g. PH, CL CG, NGPC, NRPC, TGW, GY, BY, HI, PC, SC and OC and same trend observed during second year. From quality attributes PC, SC and OC strongly positive correlate with all other attributes during both years. Moreover there is no negative correlation were found among any traits during both years (Figure 6).

DISCUSSION

Yield components

Sugarcane bagasse mulch resulted highest plant height for both hybrids in 2019 and 2020. Both hybrids showed a similar response to different mulches indicating almost similar genetic potential in both years. Highest performance is due to more organic matter and decomposition rate. In both hybrids, genetic factors affect the efficiency of mulch application. These findings are similar with (Ampofo, 2018) who observed that these mulches increase 24% plant height as compared to control. Kumar et al., (2024) reported that plant height and lead area index improved by organic mulches. Chen et al. (2023) observed the tallest plant height in mulched plots. Li et al., (2024) noted that the mulches increased plant height significantly. Cob length is responsible for the higher number of grains per plant and for the higher yield of the crop-contributing factor of the maize plant. Although the length of the cob is also a genetic characteristic of each type, its capacity will depend, in accordance with current field conditions, on the availability of nutrients to the body of the crop. By playing a role in deciding yield, the main yield contributing parameter is the cob duration. Our findings correspond to those of Yang et al. (2024). All the mulched plots gave the considerably larger cob length regarding different mulching materials. Via mulching materials, soil moisture was retained, and thus during their growth, moisture was available for

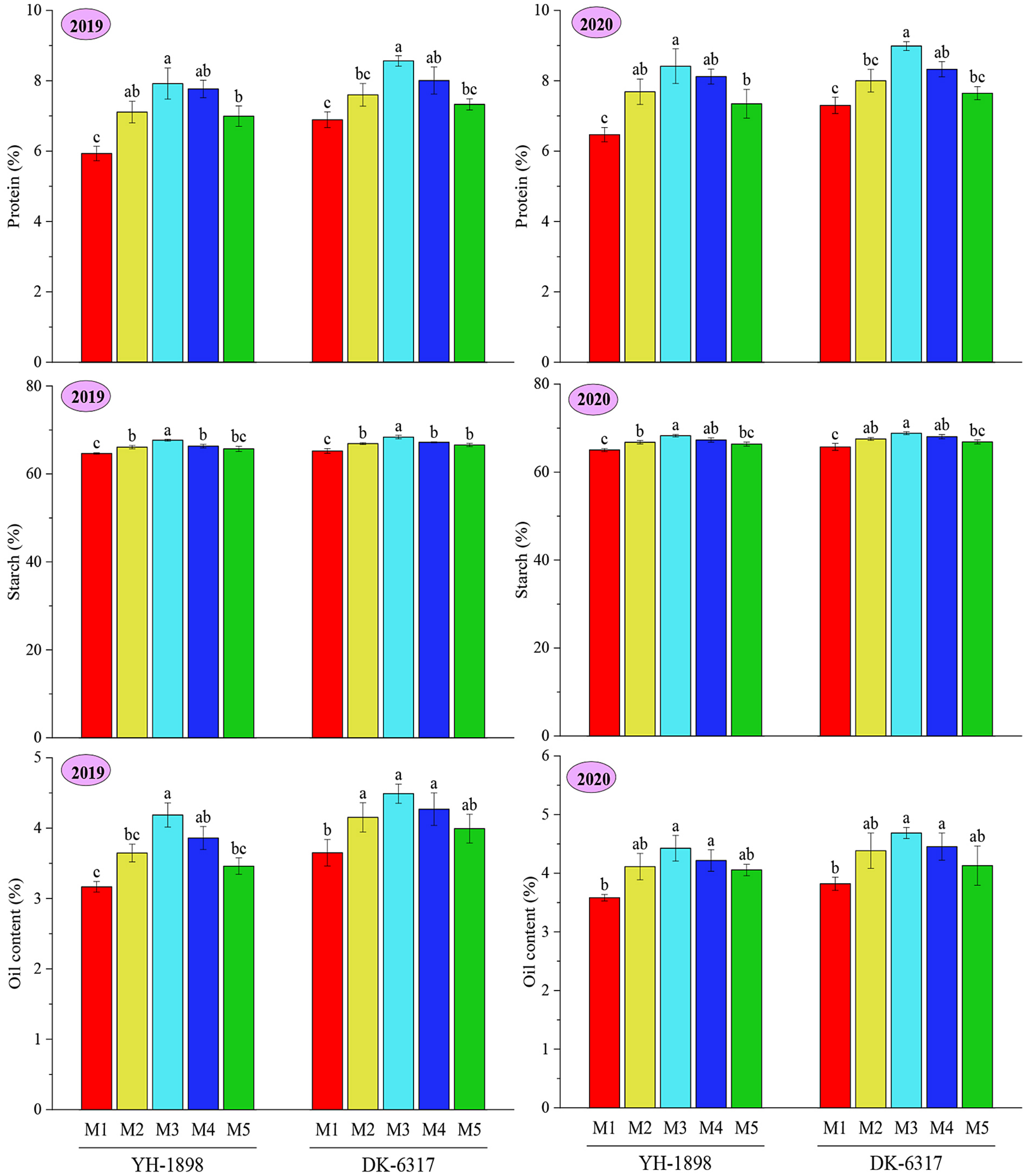

Figure 5. Effect of mulches on protein content, starch content and oil cotent percent of maize hybrids; similar letters mean non-significant ($P \leq 0.05$) differences which was calculated through LSD at 5% level of probability

growing plants. Mulch improved soil profile, increased depth of root, increased aeration of soil and suppressed weed's growth. These findings go hand in hand with research findings from (Akter et al., 2024), which suggested mulch materials increase grain yield by promoting plant height, plant number of cobs, and cob duration. Both hybrids exhibited a similar response to various mulches suggesting nearly similar genetic potential. There was no noticeable difference between the two tassel-length hybrids. A crucial component for deciding the attraction to hybrid maize is the hybrid cultivar advantage of yield over traditional varieties (Manna et al., 2024). Jaffar et al., (2024) investigate the effect of mulch (sugarcane bagasse biochar) resulting the 30% increase in

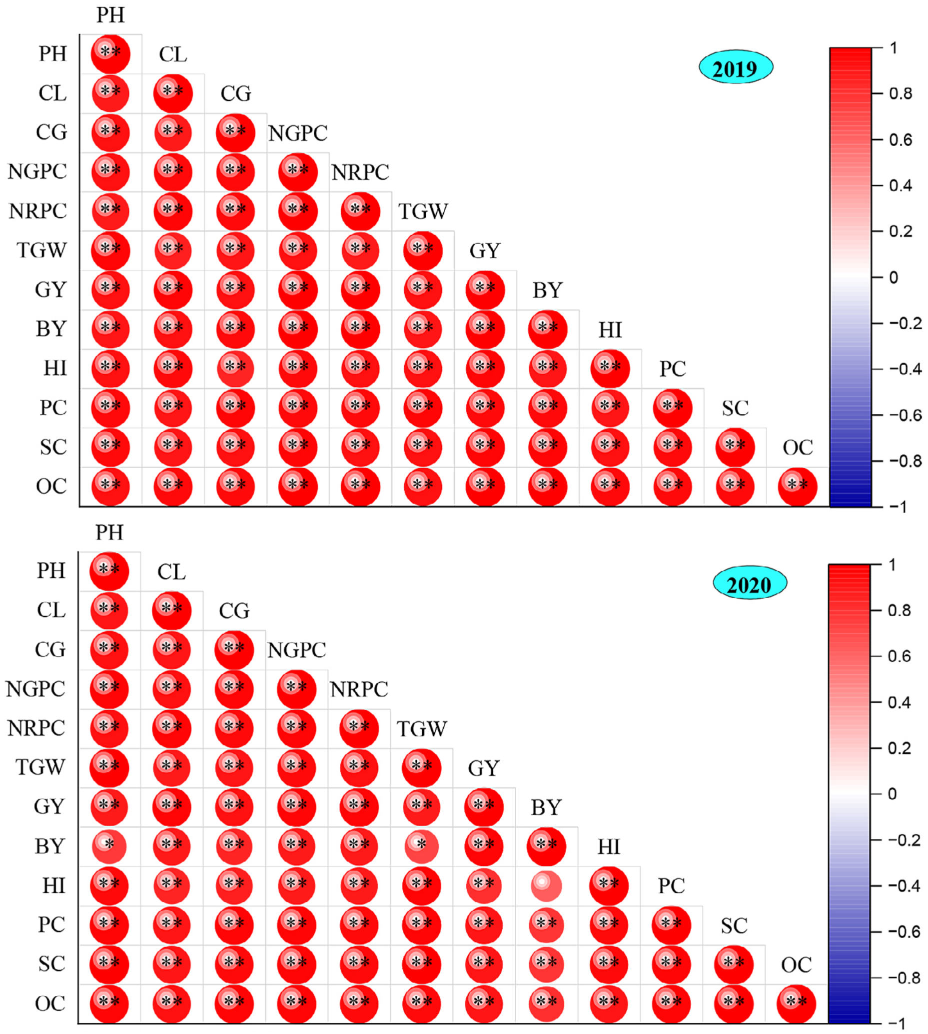

Figure 6. Pearson correlation matrix for maize hybrids traits i.e., Plant height (PH), cob length (CL), cob girth (CG), no. of grains per cob (NGPC), no. of rows per cob (NRPC), 1000-grain weight (TGW), grain yield (GY), biological yield (BY), harvest index (HI), proein content (PC), starch content (SC) and oil content (OC)
Note: * = p ≤ 0.05, ** = p ≤ 0.01.

Table 1. Effect of mulches on soil pH, electrical conductivity (EC), soil bulk density (SBD), total soil porosity (TSP) and soil organic matter (SOM) of maize hybrids

Treatments	pH		EC		SBD		TSP		SOM	
Hybrids	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
YH-1898	8.11	8.13	0.43	0.44	1.39^{a}	1.07^{a}	0.42	0.46	0.84b	0.96b
DK-6317	8.10	8.06	0.45	0.47	1.31^{b}	0.93^{b}	0.45	0.48	0.95a	1.00a
Significance	**NS**	**NS**	**NS**	**NS**	**	**	**NS**	**NS**	**	*
Mulches										
M1	8.16	8.14	0.34c	0.36c	1.51^{a}	1.15^{a}	0.32^{b}	0.38c	0.8b	0.90b
M2	8.11	8.095	0.44b	0.46b	1.35^{b}	0.99^{b}	0.45^{a}	0.48ab	0.9ab	0.98ab
M3	8.06	8.04	0.52a	0.54a	1.19^{c}	0.91^{b}	0.48^{a}	0.53a	1.0a	1.05a
M4	8.08	8.065	0.46ab	0.47ab	1.30^{bc}	0.96^{b}	0.47^{a}	0.49ab	0.9a	1.00a
M5	8.13	8.15	0.43b	0.44b	1.39^{b}	1.01^{b}	0.45^{a}	0.47b	0.9ab	0.98ab
Significance	**NS**	**NS**	**	**	**	**	**	**	**	**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: * – significant at 5% level of probability, ** – significant at 1% level of probability, ns – non-significant cob girth by 2% application of sugarcane bagasse biochar in salt effected soil resulting increase in different enzymatic activities. Similarly, Bassey et al., 2021 reported that impact of sugarcane trash mulch resulting soil organic matter and soil organic carbon that promote greater cob girth in maize. Furthermore, Yuliant et al., (2023) examine that applying sugarcane bagasse at the rate of 3–5 t ha^{-1} efficiently controls weed and preserve soil moisture that potentially leads to cob girth enhancement. Cob girth is main parameter related to the production of maize crop. It can be enhanced through adapting suitable variety & providing climatic conditions to which the plant is subjected for the development and the growth. Significantly greater cob girth was achieved in sawdust, sugarcane bagasse and wheat straw. Minimum of cob girth was documented in grass clipping. More cob girth in mulches plots is due to its increased soil holding capacity which increased the exchange capacity of the soil cation and resulted in more nutrient availability for maize plants. Straw mulch is best for weed control, according to the data from our experiment. Weed density was estimated to smaller in straw mulch plots relative to weed density in other mulch plots (Tayade et al., 2016). Aside from its effects on weeds mulch may have positive or negative effects on crops. Mulches reduce soil water evaporation and help keep the temperature of the soil steady.

Our findings are associated with Al Khafagi et al., (2025), who reported as by using mulch residues, the number of grains increased significantly. Weeds reduce the yield of crops by competing with carbon dioxide for light, water and nutrients; they can often play a role as other host for insect-pests. Weeds not only impurity the characteristics of a crop's market value but also diminish yield of the crop. Consequently, control of weeds is best strategy for sustainable agriculture. Mulch better crop rooting depth, in addition to enhancing soil structure. Mulch corrected the aeration of the soil, overcame the population of weeds, decreased evaporation of the soil and included these may be the causes of the increased amount of grain per cob. Conclusions of trial is consistent with the results of (Verma et al., 2024) who revealed that mulch materials had an effective impact on per cob's number of grains. It is a primary fact essential for final economic yield. Higher crop yields depend on a greater number of rows of grains per cob. By adjusting the appropriate and high yielding range, it can be increased. At the end of their experiment, similar results were also recorded (Kumar et al., 2024). Our findings are also consistent with those stated by Yang et al. (2024) proposed that using mulch residues, the number of grains increased significantly. Weeds decrease crop yield by compete for light, water and nutrients with carbon dioxide; they may also play a role as an alternate host for insect pests. High weeds infestation and poor weed management practices are the main reasons for crop yield low. Integrated weed management (IWM) can effectively control weeds, including biological, cultural, mechanical, chemical, and genetic methods. (Hammad et al., 2024). Dk-6317 performed better than YH-1898. Lack of competitive hybrid cultivars in the country and underdeveloped seed industries caused dependency on imported hybrid maize seeds each year (Agber et al., 2017). One important attribute is the weight of thousands of grains and in determining the final yield of grain an important role was played. Mulch is a substance covering the soil to prevent weed growth and to encourage crop plant growth. There is decline in chemical's usage. That's vital for agricultural place as it cause soil together with water preservation, improves organic matter of soil & soil's structure quality, regulates soil temperature and restores degraded soil health. For mulching purposes, sugarcane bagasse mulch is used, and is more effective in controlling field weeds (Zhao et al., 2023). Mulch promoted the depth of roots of crop along with improve the soil structure. Sugarcane bagasse mulching better the aeration of soil, suppressed population of the weeds, reduced soil evaporation, and added soil organic matter content. These are the causes of the increase in the weight of 1000 grains. These results are like the results of (Fu et al., 2022) which showed that the weight of thousands of grains was affected by different mulching materials. The stable and high yielding genotypes can fit broader regions for general cultivation. The major reasons for alterations in production between genotypes may be the maize hybrids produced by different seed companies with various genetic background.

Grain yield has considerable significance in determining yield. Grain yield coupled with other yielding parameters such as the length of the cob, no. of cobs per plant, thousand grain weight plus grain number per cob. The results are consistent with the experimental results of those who concluded (Qian et al., 2024) the yield of grain in mulched treatments has been increased. Moisture availability at any critical stage of maize growth is very necessary for both maximum growth and crop yield. Similar observations were obtained by (Verma et al., 2024) noted that organic mulch materials played an effective role in yielding maize grain. Wang et al. (2023) noted that mulches applied to soil substantially increased grain yield. By growing plant N-uptake production, minimizing N discharge losses and improving nutrient retention, mulch enhanced root and maize grain yields. (Du et al., 2022). Maize also faces many biotic and abiotic constraints during harvest as compared with other cereals. These include weeds, infestation of insect rodents and lack of nutrients (Fahad et al., 2024).

Both hybrids showed a similar response to different mulches indicating almost similar genetic potential. There was non-significant difference between two hybrids for biological yield. The hybrid cultivar yield advantage over traditional varieties is a key component in assessing the attraction to hybrid maize (Saeedinia et al., 2024). The major reasons of performance alteration among genotypes for the hybrid DK-6317 may be maize hybrids created by various seed companies with different genetic backgrounds. (Cheruiyot et al., 2022). Mulch materials preserved moisture level of soil and so moisture was obtainable to growing plants through-out their growing period. Mulch promoted rooting depth of crop along with bettering structure of soil. Sugarcane bagasse mulch improved aeration of soil, managed weeding, lowered soil evaporation with add up organic matter in soil. These are aspects which led to enhanced harvest index in mulched plots (Khan et al., 2022) provided same results from their research and concluded that mulching affected the harvest index effectively. Sugarcane bagasse mulch is used for mulching purposes and is more effective in controlling field weeds (Noor et al., 2021). Maize yield and harvest index were increased by mulching and additional irrigation, suggesting that organic manures provided growth factors and nutrient content (Moi et al., 2022).

Quality attributes

Protein is an important parameter of quality which depends on the management practices. Maize seed protein content is a valuable factor which determines both the nutritional role and nutritional quality of seed grains. The reason for the increase in the content of seed protein in mulch treatments is that organic mulches add organic matter to the soil after decay, which promotes the soil's nitrogen content. These findings are similar to those of Yuan et al. (2023). The main storage metabolite affecting crop yield and quality is starch. Carbohydrates in crop plants, primarily in the form of sucrose, are assumed to be transferred from source to sink tissues and organs via the phloem. Invertase-mediated cleavage of sucrose has been well documented to regulate the levels of plant hormones, particularly indole-3-acetic acid (IAA) which play an important role in the growth of maize kernels, directly or indirectly (Menossi et al., 2022). Both of light plus sugar control plant growth operations through coordinately modulating gene expression and enzyme activities in both carbohydrate-exporting (source) with carbohydrate-importing (sink) tissues (Fang et al., 2022).

These results are similar to experimental results from Delfine et al., (2022), who suggested that organic mulching materials add humus to soil, which plays a remarkable role in enhancing the content of seed oil. The important reasons of alteration in production between genotypes may be the maize hybrids produced by different seed companies with different genetic background. Li et al., (2024) reported from their two years research as there were effective variations in eighteen maize hybrids for the flowering plus grain yield. The difference in parameters of climate and experimental soil type can also be depicted on the output of these commercial hybrids (Tripathi and Shrestha, 2016).

Soil attributes

Soil pH is an important soil parameter which, based on the presence of base and soil acids, distinguishes between acidic and basic soil. Soil pH controls the absorption of numerous macro with micro nutrients by plants and thus directly impact the supply of nutrients by managing their chemical composition. Some plants adapt to range of rough pH and usually continue to grow. Significant soil parameter used to estimate the soil concentration of soluble inorganic salts is electrical conductivity. In terms of presence of soluble salts in soil, salinity to the soil is often stated. Soil properties such as the quality of soil moisture, porosity of the soil, temperature of the soil, and the ability to exchange cation ions have a direct influence on the soil's electrical conductivity. Goes et al., (2023) showed that mulching had a remarkable role in the electrical conductivity of the soil. Bulk density, infiltration with water retention, E.C. together with soil compaction have been found to include soil physical characteristics affected by mulching (Zhang et al., 2022). Appropriateness of the soil is essential to sustain plant growth.

The basis for biological activity and soil suitability is the physical and chemical properties of the soil (EC with hydraulic conductivity) that depend on the quality and quantity of organic matter in the soil (Lukman and Lal, 2008). Ferreira et al. (2023) depicted that mulches decreases soil electrical conductivity by 53% compared to non-mulching treatments. The argue for decreased bulk density in the mulched plots is that mulch materials significantly added organic matter to the soil after decomposition that played an active part in the compaction of soil particles that led to decreased bulk density. These findings match with the facts of Verma and Swati (2024) who noted that mulches lower the soil's bulk density. Graf et al., (2024) concluded that mulching reduces the surface soil's bulk density.

These findings are in line with Salem et al. (2021) which revealed soil physical characteristics (infiltration rate, bulk density and hydraulic conductivity) were improved by the incorporation of crop residues. Mulch activities decrease the bulk density substantially (Song et al., 2025). The bulk density was increased considerably by the 3–20 cm layer of soil. This was confirmed by Mgolozeli et al. (2025) who discovered that soil compaction increases the density and penetration resistance of soil bulk values and reduces total porosity. For different crops, Xu et al. (2024) did not observe any effect of soil density on the growth of roots along the soil profile. According to Guo et al. (2022) the higher the root diameter the greater the force exerted in the elongation phase of root meristem cells to penetrate a certain soil layer. These scientists noted a difference in the development of maize roots in the 0.0–0.2 m layer, while no difference was observed in the 0.2–0.3 m layer for the output of variable dry root matter. The characteristics of soil porosity are closely linked to soil physical behavior, root penetration and water movement (Dai et al., 2021). During the entire experimental process, mulched parcels also had a higher content of soil moisture. The highest level of soil moisture was found in parcels mulched with sawdust (Quan et al., 2024). Also, it is a vital soil parameter which plays an active role in improving soil fertility and soil health. It has performed important soil functions such as improving the availability of nutrients, soil biodiversity regulation and soil organic carbon enhancement. These findings are in line with Kucerik et al. (2024) which showed that the quality of soil organic matter was improved by mulches. These findings are consistent with those of Yang et al. (2024), which reported that the nitrogen content of soil minerals and organic matter had smaller and contradictory effects on straw mulch.

CONCLUSIONS

The study investigated the influence of different organic mulches on the growth, yield and soil physical properties of two maize hybrids. The results revealed that the application of sugarcane bagasse had the most significant impact on yield, quality and oil parameters, as well as on soil physical properties. Among the two maize hybrids, DK-6317 consistently outperformed YH-1898 across all measured parameters, demonstrating superior yield and overall performance. These findings highlight that sugarcane bagasse is an effective mulch for improving maize productivity and soil quality, with DK-6317 being the most responsive hybrid under these conditions. Consequently, this study recommends the use of sugarcane bagasse as a preferred mulch in maize production, particularly when cultivating the DK-6317 hybrid for optimal growth and yield outcomes.

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