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SCREENING OF DIFFERENT MAIZE (*ZEA MAYS*) GENOTYPES FOR SUSTAINABLE SOILLESS FODDER PRODUCTION UNDER CHANGING CLIMATIC SCENARIO

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Abstract

Fodder shortage is a significant issue in Pakistan particularly during lean periods. The first period occurs in May-June, when the Rabi fodders are depleted, while the second period arises in November-December due to the unavailability of Kharif fodders. Consequently, animals suffer from inadequate feeding and undernourishment, which adversely affects their performance. The primary obstacles to fodder production include the lack of access to high-quality seeds and production technologies among fodder growers. To combat the fodder scarcity, a soilless fodder production system was introduced in which fodder can grow without soil, low water requirement, less area, etc. The current study was carried out to evaluate the 15 cultivars of maize on the bases of their fodder yield and nutritional quality. The study was laid out under completely randomized design with four replications at Department of Agronomy, University of Agriculture Faisalabad. The results revealed that MS-2010, No. 1501, MS-2015, FSD-2020, Kissan and Sahiwal-2002 were the leading genotypes of maize with respect to root (8.55cm) and shoot length (22.67 cm), shoot biomass (35.42%), green fodder yield (37.30 kg/m^2) and water use efficiency (1.95 kg of green fodder/Litter). Moreover, the maximum crude protein (16.57%), crude fiber (14.59%), ether extract (2.58%) was accumulated in above mention genotypes of maize. MS-2010, No. 1501, MS-2015, FSD-2020,Kissan and Sahiwal-2002 genotypes exhibit higher yields and superior nutritional quality, thereby offering potential solutions to combat the fodder crisis.

Keywords: Climate, Crude Protein, Fodder Yield, Livestock, Maize, Soilless Fodder.

1. INTRODUCTION

Livestock is major contributor of the agriculture GDP of Pakistan and livestock sector depend on good quality of fodder that is the main feed for ruminants productivity. This sector has emerged as the largest contributor to Pakistan’s agriculture accounting for 62.68 percent of the agriculture value added and 14.36 percent of the national GDP grew at 3.78 percent during financial year 2022-23 (Govt. of Pakistan, 2023).

Poor quality fodder/feed negatively impact accounts for livestock productivity and reproductive efficiency. The livestock industry is a crucial component of Pakistan's agricultural sector, playing a significant role. However, the milk production capacity of

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lactating animals is not reaching its full potential. Several factors contribute to this low productivity, including inadequate and imbalanced feeding practices, limited reproductive skills, susceptibility to various diseases, and a lack of essential support activities and services like artificial insemination methods (Govt. of Pakistan, 2022).

Furthermore, growing fodder is land, capital, input and labor requiring on continuous time scale basis and intensively results in increased cost of production as well as full time grower concern (Gunasekaran et al., 2022). Fodder availability in all environments in general and under urban and peri-urban regions in particular affects surety of fresh green fodder to livestock (Omollo et al. 2018). Furthermore, growing fodder is land, capital, input and labor requiring on continuous time scale basis and intensively results in increased cost of production as well as full time grower concern.

Provision of quality milk and meat entirely depends on fodder provision which become more imperative for concentration of livestock farmers under urban and peri-urban environments where transportation of fresh fodder in timely fashion is another liability (Rustis et al. 2018). Urbanization is one key reason behind less hectarage under fodder crops particularly in high populated regime of the world (Ernest et al. 2017).

In such populated regimes peri-urban lands are getting depleted due to housing, industrial and civil infrastructure. Sewage and sludge-based depositions resulted from big cities deteriorating the soil and in surroundings heavy metal accumulation is another poisonously damaging impact on fodder grown areas and by providing passage for inculcation of these deleterious elements in life chain (Jemiimah et al., 2018; Abu Hatab et al., 2019).

The fodder scarcity can be overcome by adopting soilless fodder production system (SFPS) technique and this technique is used for green fodder production of many forage crops like wheat, oat, barley, maize etc under a hygienic environment free of chemicals like insecticides, herbicides, fungicides, and artificial growth promoters and as well as fodder can be produced throughout the year by using less water consumption (Al-Hashmi, 2008; Dogrusoz, 2022). Soilless fodder requires short period for growth around 7-10 days and does not require high-quality arable land, but only a small piece of land for production (Al-Karaki, 2011; Farghaly et al., 2019; Gebremedhin, 2015; Dung et al., 2010).

It has extraordinary protein, vitamins, fiber and mineral contents with their healthy beneficial effects on animals (Boue et al., 2003). Therefore, this technology is an important agricultural technique currently used in many countries (Tudor et al., 2003). All these special features of soilless system, in addition to others make it one of the most important agricultural techniques currently in use for green forage production in many countries especially in arid and semi-arid regions of the world. However, determine the best forage crop is an important matter in producing highest fodder yield and quality and at the same time considering the economic dimensions in the process of soilless green fodder production by saving of seeds costs (Bradley and Marulanda, 2000; Bhat et al., 2021). Many crops like wheat, oat, barley and maize can be grown under soilless fodder production system and need to evaluate the high potential genotypes of wheat, oat, barley and maize with respect to green fodder yield, dry matter and crude protein (Ansar et al., 2010; Champan et al., 2012; Newell et al., 2021). Different research works on different crops cultivars and finds that cultivars have a significant effect on green fodder production and protein content. The variation in maize varieties and environmental factors, such as humidity, differs across countries, necessitating the assessment of soilless fodder production using different varieties that are suitable for the prevailing natural conditions (Farghaly et al., 2019; Indira et al., 2020). However, in Pakistan multiple fodder varieties of maize are available and till to date no research has been conducted to evaluate the potential of available fodder varieties in soilless production system (Subhani et al. 2015). Therefore, there is dire need to evaluate available genotypes of wheat, oat, barley and maize for identifying the high yielding and nutrition varieties under soilless fodder production system.

The current study was aimed to evaluate the potential of some maize genotypes for green fodder production, quality and water use efficiency under intensive soilless conditions. The main objectives of this study are localizing the know-how of using soilless culture in producing green fodder (sprout) in Pakistan while investigated the suitable maize genotypes use under soilless culture.

2. MATERIALS AND METHODS

The experiment was conducted at Graduate Laboratory, Department of Agronomy, University of Agriculture Faisalabad, in 2022, following a completely randomized design with four replications. The study focused on fifteen genotypes of maize (*Zea mays*). The crop duration lasted for ten days, after which the fodder was used as feed for animals. Various phenological, yield and proximate traits of soilless fodder were analyzed. Parameters such as shoot and root length, root and shoot biomass, green fodder yield, seed to fodder ratio, water use efficiency, dry matter, moisture content, ash content, crude protein, crude fiber, ether extract, chlorophyll *a* and *b* content, total chlorophyll content, carotenoid content, and nitrogen content were evaluated.

2.1 Planting Materials

Fifteen different genotypes of maize seeds were obtained from various sources, including the local market, Maize and Millet Research Institute in Yousaf Wala Sahiwal, Fodder Research Institute in Sargodha, and Ayub Agriculture Research Institute in Faisalabad, Pakistan. The names of these genotypes are Kashmir Gold, Sahiwal-2002, Golden, Agaiti-2002, MS-2010, MMRI-Yellow, Kissan, FSD-2018, MS-2010, Sgd-2002, YHM-113, No.1501, C.7065, YHM-112, and FSD-2020. The first step in the process involved cleaning the seeds to remove any dirt or other foreign materials. Seed rate of different maize genotypes was kept 6 kg/m^2 under soilless fodder production system.

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2.2 Seed treatment

To prevent any potential attacks of fungus or insects, the seeds of various maize genotypes were treated with 20% sodium hypochlorite solution for 20 minutes. In addition, the trays were cleaned and disinfected using the same solution. To enhance germination before planting, the seeds were first washed with water and then soaked in water for a duration of 12 hours. This pre-soaking process aims to reduce the time required for germination and improve the overall germination percentage. During the process of imbibition, the water is initially absorbed by the seed coat and subsequently taken by the embryo and endosperm, initiating the germination process. Following the soaking process, the different maize genotypes were placed in steel trays with dimensions of 12"×18", which featured drainage holes to remove excess water.

2.3 Irrigation

The trays were manually watered with tap water at four-hour intervals, providing a total of 50 mL per tray per day, which effectively maintained the seeds' moisture. Drained water was collected in plastic cups which were placed under planting tray, and the amount was recorded for calculating water use efficiency.

2.4 Harvesting

The crop was harvested after ten of days sowing. During the harvesting process, growth, yield and proximate traits were taken.

3. PROCEDURE

a. Water use efficiency (Kg of green fodder yield/L)

Water use efficiency was measured by the following formula.

$$Water\ use\ efficiecny = \frac{Total\ green\ fodder\ yield\ kg\ m^{-2}}{Total\ water\ used\ (Liter)}$$

3.2 Dry and moisture content

Dry matter percentage was determined by using standard procedure of AOAC (2006). Took 200 g sample of forage in aluminum dish and heat up the sample in hot air oven at 108°C followed by 3 hours cooling and samples weight was done.

$$\text{Dry matter (\%)} = \frac{\boldsymbol{weight\ of\ dry\ matter}}{\boldsymbol{weight\ of\ sample}} \times 100$$

$$Moisture\ content\ (\%) = \frac{\text{Loss of weight}}{\text{Weight of sample}} \times 100$$

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3.2 Crude protein

To determine the nitrogen % age Kjeldahl method was used as per 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 feed sample.

Took 1g of the dried feed sample, added 5g digestion of mixture that was consisted of 90 parts K2So4 (to raise the boiling points), three parts of FeSo4 and seven parts of CuSo4 (act as catalyst) both digestion mixture and feed sample put into digestion flask (500 mL) and added 25-30 commercial H2SO4 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 10mL 4% NaOH solution, whereas in another flask took 10 mL boric acid added and add one drop of methyl red as an indicator, heated till the fumes of ammonia had appeared and NH3 gas is trapped by 4% H3Bo4. 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 H2So4 till golden yellow color appeared and recorded the volume of acid used.

$$\text{N (\%)} = \frac{Volume\ of \frac{N}{10}\ \text{H2So4} \times 0.0014 \times \text{vol.of sample dilution}}{Wt.of\ sample \times volume\ of\ solution\ used\ (10mL)} \times 100$$

Crude Protein (%) **=** N% ×6.25

3.3 Determination of chlorophyll and carotenoid content (mg g^{-1} FW)

The chlorophyll *a, b* and total chlorophyll content were determined by the method of Arnon (1949). First, took 0.5g of fresh leaves and cut into piece then 80% acetone were added into test tube for extraction and kept for overnight at -10ºC.

The extract was centrifuged at 1400 rpm for five minutes and then run the sample in spectrophotometer at 663, 645, 480 nm wavelength after absorbance reading were noted from spectrophotometer.

The chlorophyll *a, b* and carotenoid were determined by the following equation.

$$\text{Chl.}\, a = [12.7(\text{OD } 663) - 2.69(\text{OD } 645)] \times \text{V}/1000 \times \text{W}$$

$$\text{Chl.}\, b = [22.9(\text{OD } 645) - 4.68(\text{OD } 663)] \times \text{V}/1000 \times \text{W}$$

V= Volume of the extract (mL)

W= weight of the fresh leaf tissue (g)

Carotenoid = $(\text{OD } 480) + 0.114\ (\text{OD } 663) - 0.638\ (\text{OD } 645)]$.

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3.4 Statistical analysis

Analysis of variance was done using completely randomized design and treatments means were compared by employing HSD test. Moreover, Pearson correlation analysis was performed by using two tailed t-test (df-2) among all traits with the help of OriginPro-2021 SR0 software.

4. RESULTS

4.1 Root and Shoot length (cm)

Different maize genotypes exhibited significant difference on root and shoot length in Fig.1. Results showed that the tallest root length (2.59 cm) was taken in accession 1501 that was statistically at par with MS-2010, FSD-2018, Kissan and Sgd-2002 whereas the shortest root length was exposed in YHM-112 that was statistically alike with C.7065. For shoot length the longest shoot length 22.67cm was recorded in MS-2010 and the shortest shoot length was measured in Kashmir Gold

4.2 Root and Shoot biomass (g)

Fig. 1 indicated the significant response of different genotypes on root and shoot biomass ($p \leq 0.01$). Results depicted that MS-2010 had attained the highest shoot biomass that was statistically at par with line1501 and Sgd-2002 whereas the lowest shoot biomass was measured in Kashmir Gold. Likewise, the maximum root biomass was accumulated in Kashmir Gold while the least biomass was gathered in MS-2010 and No.1501.

4.3 Green Fodder yield (Kg m^{-2}) and seed to fodder ratio

Data regarding green fodder yield and seed to fodder ratio responded significant for different genotypes of maize (Fig.1). MS-2010 had attained the maximum green fodder yield (37.30 kg m^{-2}) whereas, the least green fodder yield was recorded in Kashmir Gold. In case of seed to fodder ratio, the maximum seed conversion into fodder was recorded in MS-2010 while the lowest conversion took place in Kashmir Gold.

4.4 Water use efficiency (Kg of fresh matter/L)

Results regarding water use efficiency, maize genotypes exhibited significant response (Fig.2). The least water consumed for producing green fodder yield was recorded in Kashmir Gold (1.32 kg of fresh matter/L) that was statistically similar with FSD-2008 and Kissan maize whereas, the highest was consumed in MS-2010 maize for producing fodder.

4.5 Proximate analysis

4.5.1 Dry matter and moisture content (%)

Dry matter content and moisture content of maize genotypes exhibited significant response (Fig.2). MS-2010 (15.46%) has the leading genotypes with respect to dry matter content whereas, the least dry matter content was accumulated in Golden maize

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(14.50%). Likewise, the highest moisture content was recorded in Golden maize that was parity with Kashmir Gold and the lowest moisture content was gathered by MS-2010 and No. 1501 (Fig.2).

4.5.2 Crude protein and ether extract %

Maize genotypes imposed statistically significant impact on available crude protein and ether extract on fodder grown under soilless fodder production system (Fig. 2). Results exposed that the maximum crude protein and ether extract was accumulate in MS-2010 that was statistically at par with No.1501 whereas the minimum crude protein and ether extract was recorded in Kashmir Gold and Sahiwal-2002.

4.5.3 Crude Fiber and ash content %

Statistically, the maximum crude fiber was accumulated in MS-2010 genotypes that was statistically alike with No.1501 while the minimum crude fiber content percentage was gathered by Kashmir Gold maize genotypes (Fig. 2). Moreover, the leading ash content maize genotypes was observed in MS-2010 followed by No.1501 whereas the least ash content was recorded in Kashmir Gold and Sahiwal-2002 (Fig. 3).

4.5.4 Ether extract and nitrogen free extract %

Results showed that the maximum ether extract was accumulate in MS-2010 that was statistically at par with No.1501 whereas the minimum ether extract was recorded in Kashmir Gold and Sahiwal-2002 (Fig. 2). Statistically, different maize genotypes exhibited significant response to nitrogen free extract. The maximum nitrogen free extract percentage in Kashmir Gold whereas the least nitrogen free extract was accumulated in MS-2010 maize genotype (Fig. 3).

4.6 Physiological attributes

4.6.1 Chlorophyll *a, b* and total chlorophyll content and carotenoid (mg g^{-1} FW)

Different maize genotypes exhibited statistically significant response ($P \leq 0.01$) on leaf chlorophyll *a, b*, total chlorophyll and carotenoid content of soilless maize fodder (Fig.3). Kissan and Sahiwal maize genotypes responded maximum toward chlorophyll *a, b* and total chlorophyll content where the minimum value was observed in Golden and C.7065 maize genotypes. Moreover, the highest carotenoid content was taken in Kissan followed by Sahiwal-2002 and MS-2010 respectively whereas the lowest content was accumulated by C.7065 that was statistically on par with Sahiwal-2002 and FSD-2020.

4.6.2 Sodium content (mg/100g)

Statistically, MS-2010 maize genotype exhibited the maximum sodium content and statically at par with No.1501 that is followed by Sgd-2002 whereas the minimum sodium was recorded in Kashmir-Gold maize genotype (Fig.4).

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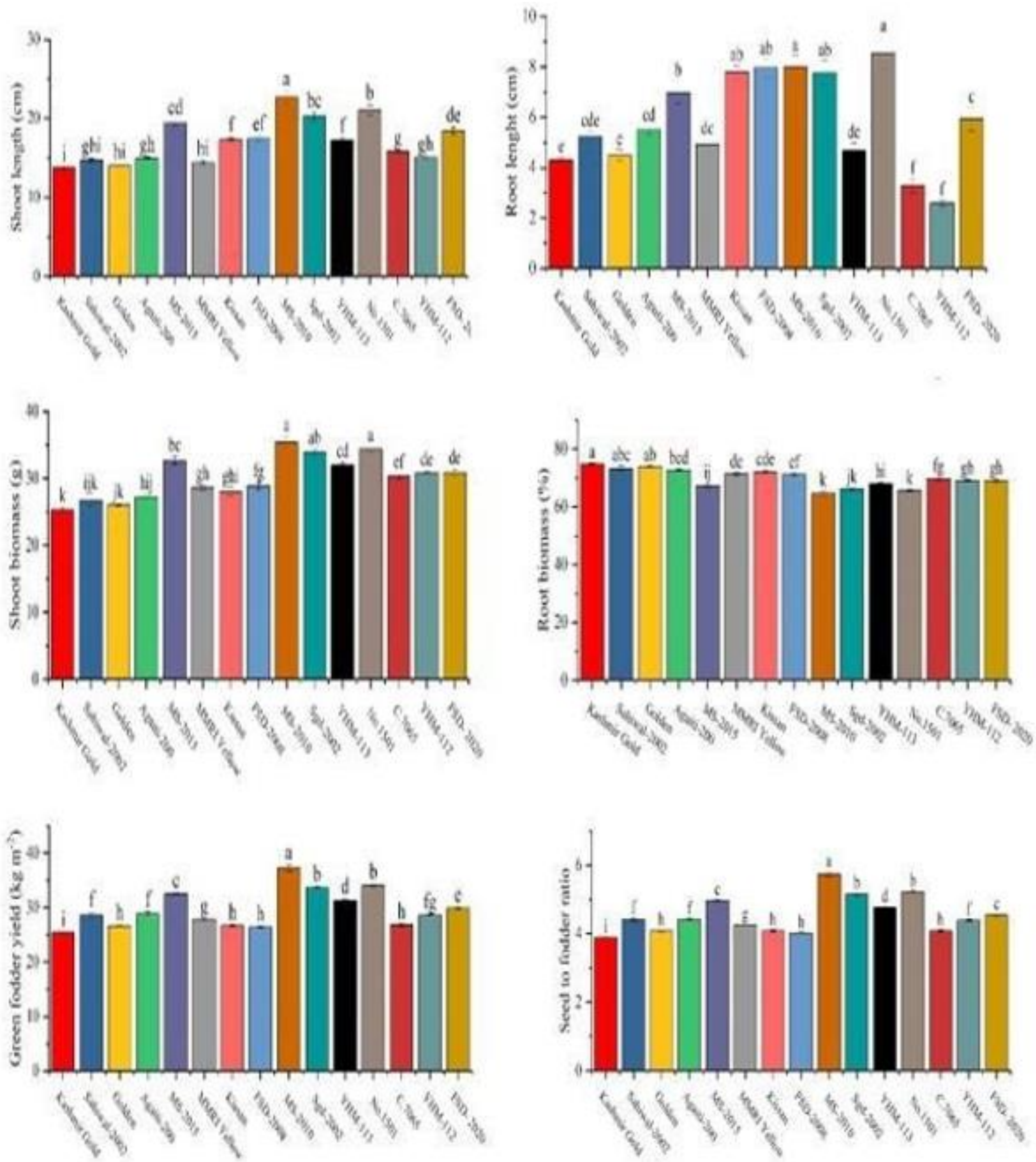

Fig 1: Effect of different genotypes of maize (*Zea mays*) on root length (cm), shoot length (cm), root biomass (g), shoot biomass (g), green fodder yield (kg m^{-2}) and seed to fodder ratio under soilless fodder production system ($P \leq 0.01$)

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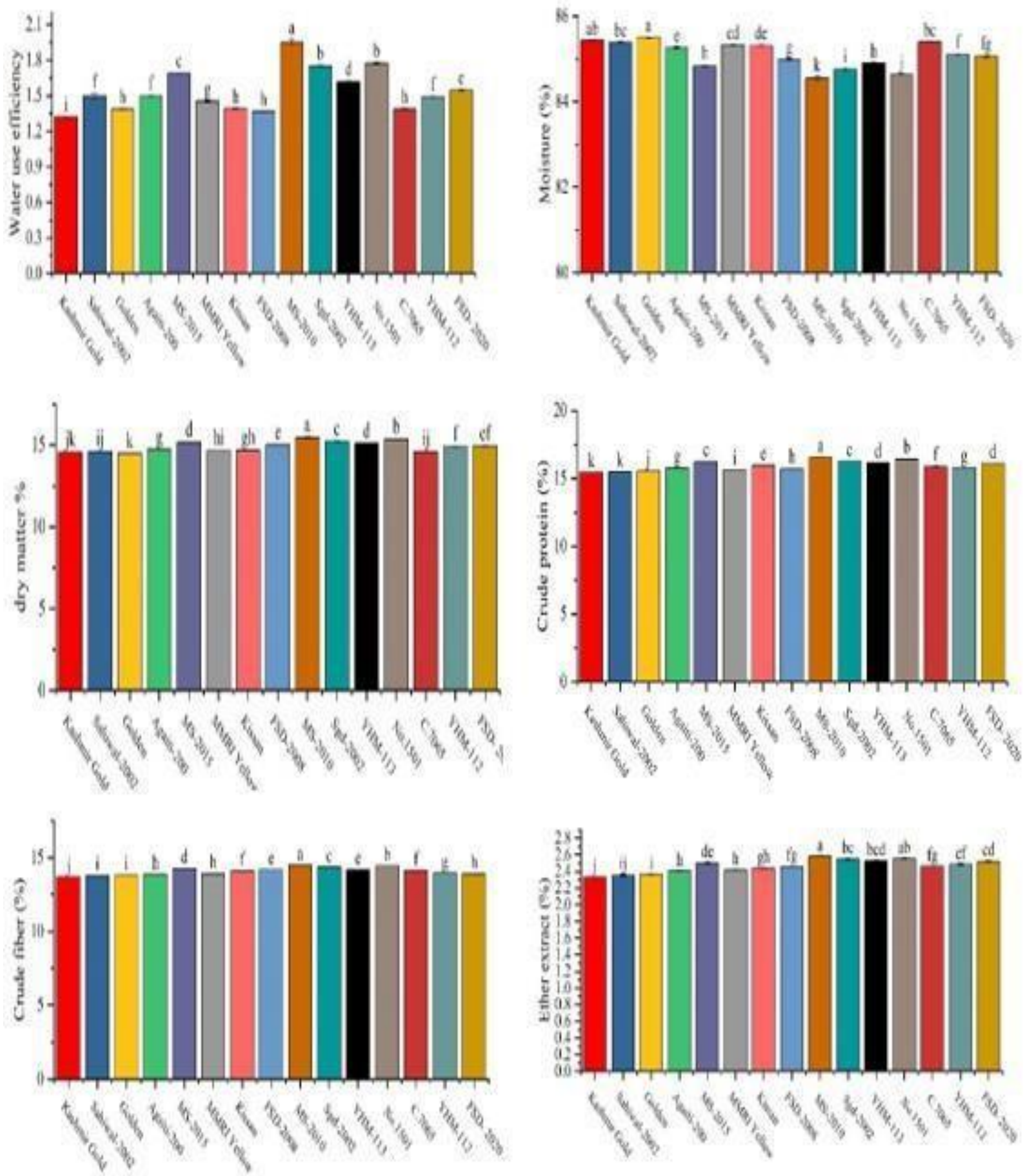

Fig 2: Effect of different genotypes of maize (*Zea mays*) on water use efficiency, moisture content (%) dry matter content (%), crude protein (%), crude fiber (%) and ether extract (%) under soilless fodder production system (P≤0.01)

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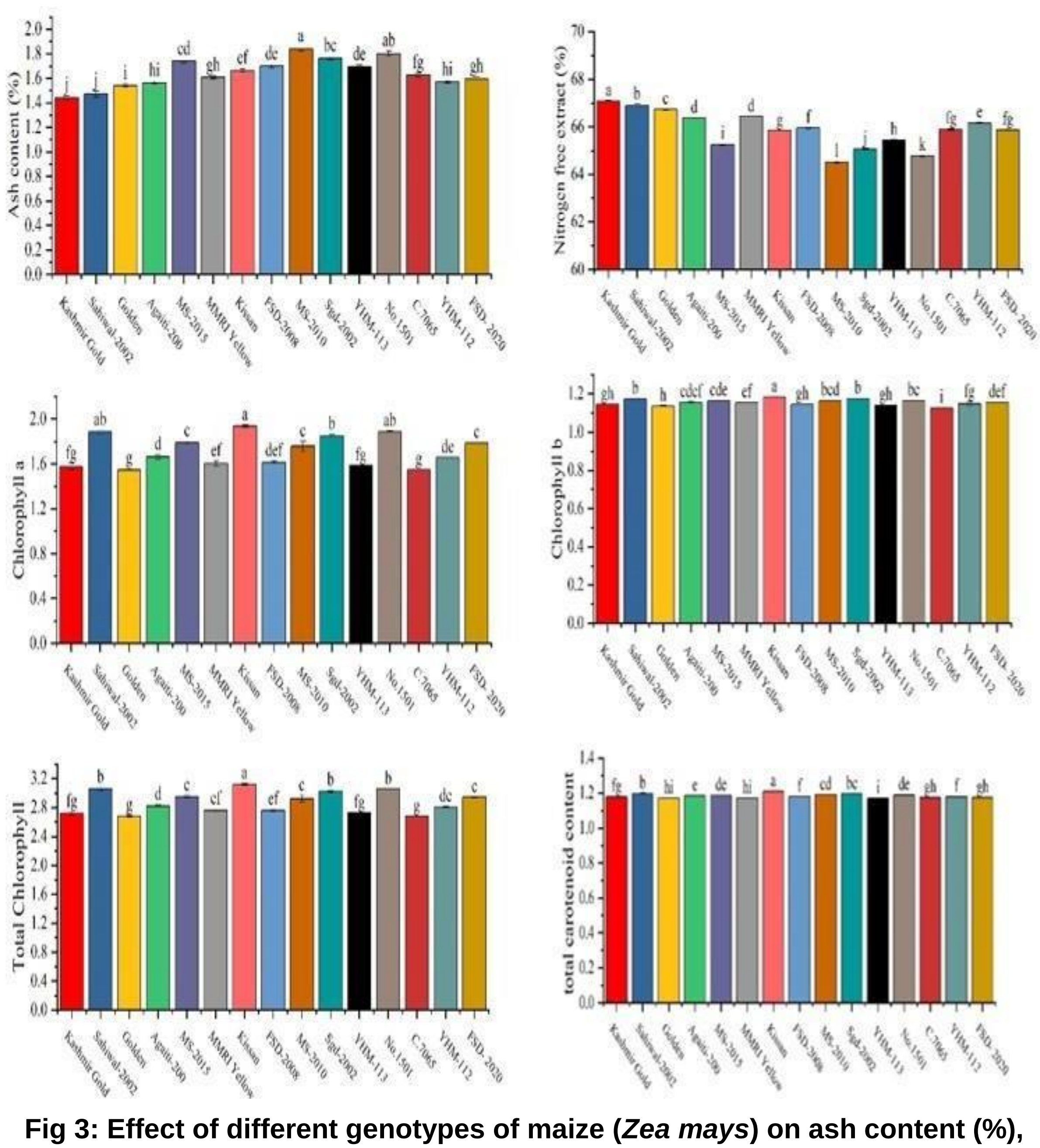

Fig 3: Effect of different genotypes of maize (*Zea mays*) on ash content (%), nitrogen free extract %, chlorophyll *a* content (%), chlorophyll *b* content (%), total chlorophyll content (%) and carotenoid content (%) under soilless fodder production system (P≤0.01)

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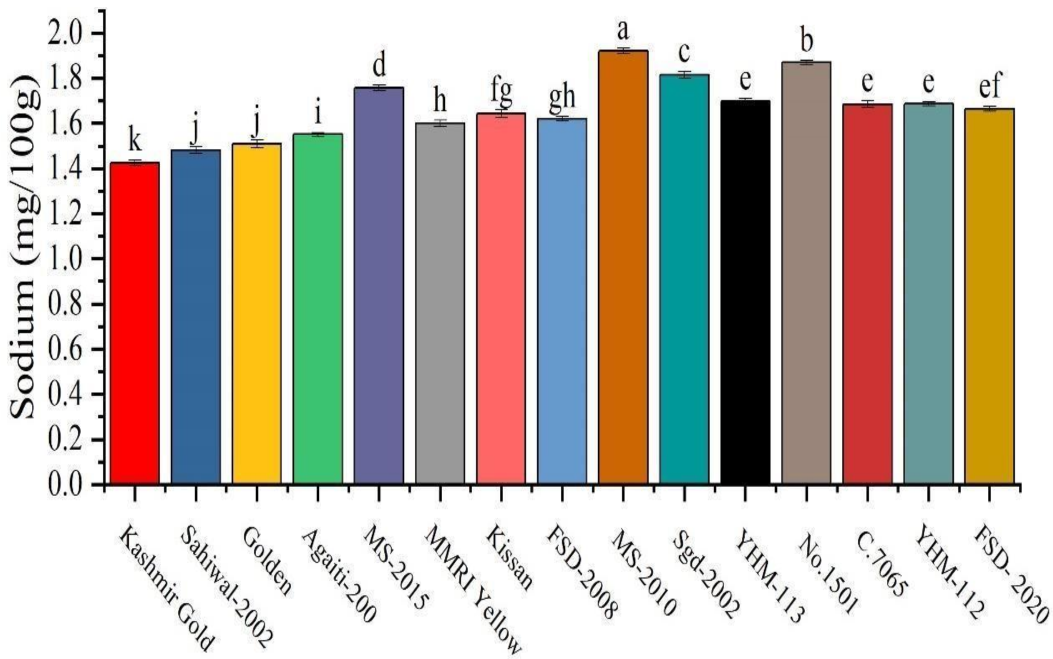

Fig 4: Effect of different genotypes of maize (*Zea mays*) on Sodium (mg/100g) under soilless fodder production system (P≤0.01)

4.7 Correlation Description

The correlation between different traits of maize genotypes was shown in Fig.5. Green fodder yield and seed to fodder ratio have positive correlation with root, shoot length and shoot biomass whereas negative significant correlation with root biomass.

Water use efficiency has significant positive correlation with shoot, root length, shoot biomass, green fodder yield whereas, negative significant correlation was recorded with root length.

Crude protein, crude fiber and ether extract have positive significant correlation with shoot, root length, green fodder yield and water use efficiency whereas negative significant correlation was exposed with root biomass.

Figure showed that chlorophyll *a, b* and total chlorophyll content have negative significant correlation with root biomass and non-significant positive correlation with moisture content while significant positive correlation was depicted with root, shoot length, shoot biomass, green fodder yield, seed to fodder ratio while non-significant positive correlation was recorded with dry matter content, crude fiber, crude protein and ether extract.

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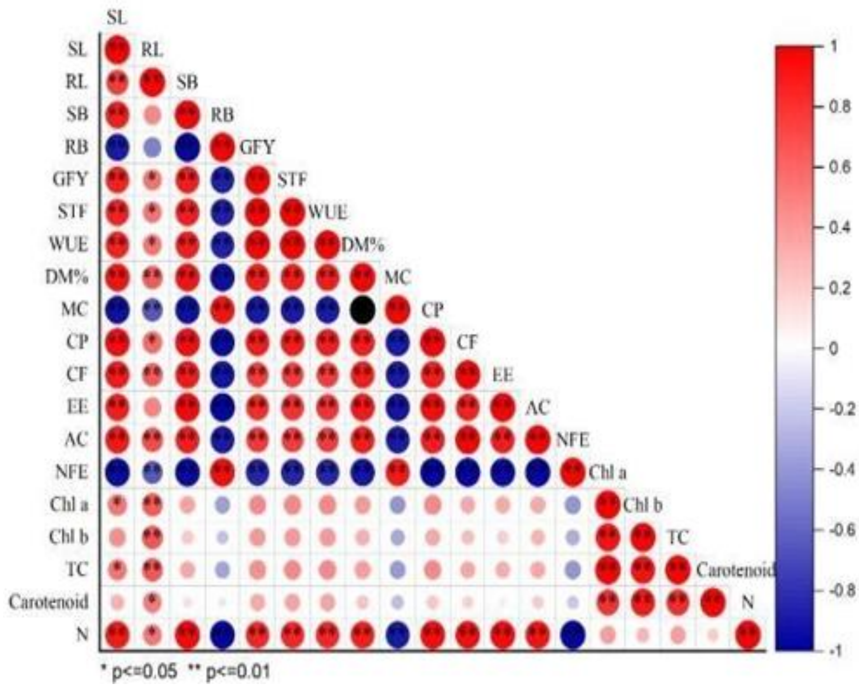

Fig 5: Correlation assessment among different study triats i.e. shoot length (SL), root length (RL), shoot biomass (SB), root biomass (RB), green fodder yield (GFY), seed to fodder ratio (STF), water use efficiecny (WUE), dry matter (DM), moisture content (MC), crude protein (CP), crude fiber (CF), ether extract (EE), ash content (AC), nitrogen free extract (NFE), chlorophyll *a* content (Chl a), chlorophyll *b* content (Chl b), total chlorophyll content (TCC), carotenoid content and Sodium (Na)

4. DISCUSSION

Screening of cereal germplasm is an important aspect for high-yielding and nutritionally rich crops performing under a set of environmental or control condition regimes. Site and condition specific protocol of production technology are therefore needed to get the optimum yield through exploitation of available set of interventions. In the subject experiment, various genotypes of cereals were grown under controlled conditions (soilless environment) for their fodder appraisal by using traits such as shoot length, root length, biomass weight in dry and fresh forms, water use efficiency, green fodder yield, chlorophyll content, phenolic and carotenoid contents as well as nutritional traits i.e., crude protein, crude fat, ether extract, and ash content etc. Findings exposed significant variation in performance of employed genotypes was quantified. A total of fifteen genotypes of maize were employed during study and they were evaluated on the bases of green fodder yield and proximate analysis. Growing cereals in steel trays with huge seed rate per unit area gives ample support and environment to seeds to germinate, emerge and stand for a few days which may be affected by their genetic makeup or early

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stage and frequency of moisture availability (Tian et al., 2014). Hence, assessment of such seed germination and early growth becomes important for assuring rate, speed and uniformity of biomass production. Enormous studies are evident that better growth at the early stage can be foreseen by involving practices such as maintenance of required temperature and humidity (Monteiro et al., 2021). Keeping these facts in mind, performance of cereal fodder judged can help devise better strategy to rear and obtain required fodder yields with better nutritional status. Varieties with better shoot and root lengths emerged to be good material for obtaining fodder yields and fodder to seed ratios while, determining quality of these cereals at early growth stages might vary with respect to employed cereal type and stage of growth (Piltz et al., 2021). In our study the root biomass and shoot biomass were ranged from 65.26 to 74.82 % and 25.29 to 35.42% respectively that were similar with the finding of Jeminah et al., (2018) and Naik et al. (2017) who reported root and shoot biomass 68.58 to 70.52%, 30.49 to 31.42% respectively. The higher root biomass in hydroponic maize fodder is a result of the presence of a root mat alongside the seeds. On the other hand, the higher shoot biomass in land-grown maize fodder is due to the loss of seeds during germination and the removal of roots during fodder harvesting. The current study regarding moisture content, crude protein revealed that moisture content, dry matter, crude protein crude fiber, nitrogen free extract are accordance with (Jemimah et al., 2015). In our finding, 5-6 kg fodder was produced from one kg of maize seed that was comparable with the results of Naik and Sing, (2013) and Jemimah et al. (2018) who reported 5 to 6 kg and 4 kg fresh fodder yield from one kg of maize seed under soilless fodder production system (SFPS). The finding of fresh green fodder yield was also aligned with Al-Ajmi et al. (2009) and Lamnganbi and Surve (2017).

The differences in fodder yield among studies may be ascribed to variances in the maize varieties employed or variations in the degree to which environmental factors, such as humidity and temperature, were effectively controlled, given the utilization of commercial fodder units. The nutritional value of fodder produced under soilless fodder production system reported that 15.46% dry matter that are similar with the finding of Gebremedhin (2015), Dadhich (2016) and Jemimah et al. (2018). Different types of soilless fodder exhibit variations in their dry matter content, which could be attributed to differences in growth rates. This variance in growth rates may be linked to the rate at which starch stored in the seeds is converted into simple sugars, generating energy while emitting carbon dioxide and water. Results exhibited that 16.57% crude protein was recorded in out experiment that was resemblance with the study of Dadhich, (2015); Jemimah et al. (2018). Moreover, 1.84% ash content, 67.09% nitrogen free extract,14.49% crude fiber and 2.58% ether extract were produced from different genotypes of maize under soilless fodder production system and that are in line with the results of (Dadhich, 2016; Adekeye et al., 2020; Sing et al., 2022). Moreover, conventional fodders are less nutritious than the soilless fodder and the During the sprouting process, there is a shift in nutrient composition in maize fodder. This leads to specific alterations, including an increase in crude protein, ether extract, and nitrogen-free extract (carbohydrates). Simultaneously,

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there is a decrease in crude fiber, total ash, and insoluble ash. More specifically, sprouting triggers the breakdown of complex compounds and activates enzymes, resulting in the release of nutrients and subsequent changes in their proportions. The increase in crude protein suggests that sprouting enhances the availability and synthesis of proteins within the maize fodder. The rise in ether extract indicates a higher fat content, while nitrogen-free extract represents the amount of carbohydrates remaining after the removal of nitrogen-containing compounds (Putnam et al., 2013; Gebremedhin, 2015).

5. CONCLUSION

The results of the study exposed that different genotype of maize showed variation among green fodder yield, seed to fodder ratio, shoot and root biomass, crude protein, crude fiber etc. MS-2010 attained the maximum green fodder yield (37.30 kg m^{-2}) followed by Sgd-2002 genotype. Additionally, the maximum seed to fodder conversion ratio took place in MS- 2010 genotypes where one kg of maize seed produced 5.74 kg of green fodder yield. Moreover, the maximum crude protein, crude fiber was assimilated in MS-2010, No.1501, Sgd-2002, Agaiti-2002 and MS-2015 maize genotypes.

6. FUTURE RECOMMENDATION

Based on the findings of the study, future recommendations are promotion of high-yielding and nutritionally superior maize cultivars such as MS-2010, No. 1501, MS-2015, FSD-2020, Kissan, and Sahiwal-2002 for widespread adoption among fodder growers as well as implementation of soilless fodder production systems to mitigate the effects of limited land availability and water resources, thereby increasing fodder production efficiency.

Conflict of interest:

The authors have no conflict of interest

Author contribution:

MA conducted the whole study SZ, SH, AZ guided and supervised the whole study.

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