# Agronomic interventions for production and preservation of quality maize (*Zea mays* L) fodder - A review

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## Abstract

Maize is used as animal fodder throughout the world and considered as ideal forage because of its quick growing habit, produces high palatable biomass and helps to improve body weight and milk quality in cattle due to its higher nutritional value. Production potential of forage maize can be altered with changes in agronomic practices viz. selection of cultivar, planting density, weed management, nutrient management, corn-legume intercropping etc. Maximum productivity of quality green fodder can be achieved by exploring best agronomic practices for its cultivation. Under conventional feeding system, farmers practice's daily cutting and carrying of fodders for feeding to the livestock is laborious method and also results in increase in lignin content of fodder crop with maturity, thus requires more energy to digest, effecting net energy balance of the animals. Corn silage production has been seen to suffice all these factors which can help in managing round the year fodder availability for dairy animals. The production of quality corn silage depends upon number of agronomic factors such as selection of cultivar, stage of harvesting, method of storage, corn-legume mixture silage etc. Keeping these points in view, the literature pertaining to agronomy of cultivation of fodder maize and its preservation, to obtain higher biomass of quality fodder and silage has been reviewed.

## Abbreviations

ADF - acid detergent fibre
ADL- acid detergent lignin
B:C ratio - benefit cost ratio
CP - crude protein
DAS - days after Sowing
DDM - digestible dry matter
DM - dry matter
DMD- dry matter digestibility
DMI - dry matter intake
DMY- dry matter yield
DMR - dry matter recovery
GFY- green fodder yield
HW - hand weeding
MLS - milk line score
NDF - neutral detergent fibre
NPK - nitrogen, phosphorus and potassium
OM - organic matter
QPM - quality protein maize
RDF - recommended dose of fertiliser
WSC- water soluble carbohydrates

## Introduction

Green forages are considered among the most important factors for successful dairy farming. The inadequate supply of green fodder around the year is one of the main reasons for the low productivity of dairy animals. Successful management of livestock involves optimizing the availability of feed with the requirement of animals as efficiently and economically as possible. For higher production and economic returns from the dairy farming sector, a regular supply of fodder is very essential (Brar *et al.*, 2016).

Cultivated fodder, crop residues, permanent pastures, and grazing lands are the major sources of fodder supply. In the Indian subcontinent, there is a multiplicity of forage crops grown in different seasons and regions. The crops grown for fodder are non-commercial in nature and production of forage is from degraded and marginal lands with minimal inputs. These all factors led to a huge gap in the demand and supply of green fodder (Gosh *et al.*, 2016). The available forages are poor in quality with lower levels of available energy,

**Table 1 - Non-legume fodders crops**

| Fodder Crop | Physiological stage of harvesting | Harvesting Stage (DAS) | Crude Protein (%) | In-Vitro DMD (%) | References |
|---|---|---|---|---|---|
| Maize | Silk to Milk stage | 55-65 | 8-11 | 52-68 | Gupta *et al.*, 2004 |
| | Milk to dough | 55-60 | 8.02 | 58.16 | Wadhwa *et al.*, 2010 |
| | 50 % flowering | -- | 7.15 | -- | Kar *et al.*, 2016 |
| Bajra | Boot Stage | 45-55 | 7-10 | 55-62 | Gupta *et al.*, 2004 |
| | Ear initiation | 45-50 | 6.95 | 48.76 | Wadhwa *et al.*, 2010 |
| Sorghum | Initiation of flowering | 70-80 | 7-8 | 57-60 | Gupta *et al.*, 2004 |
| | Boot to milk stage | 75-80 | 7.22 | 52.26 | Wadhwa *et al.*, 2010 |
| | 50 % flowering | -- | 8.18 | | Kar *et al.*, 2016 |
| Teosinte | Pre-flowering | 80-85 | 7-9 | 58-62 | Gupta *et al.*, 2004 |
| Sudex | Subsiquent cutting after 30 days | 65-70 | 7-11 | 55-60 | |
| Napier Bajra Hybrid | One-meter height | 55-60 | 7-11 | 55-60 | |
| Guinea Grass | One-meter height | 55-60 | 8-10 | 57-60 | |
| Sugargraze | 50 % flowering | -- | 10.42 | -- | Kar *et al.*, 2016 |

DMD- dry matter digestibility

proteins, and minerals. Farmers maintain large herds of animals to compensate for the low productivity, which adds to the pressure on fodder and other natural resources (Palsaniya *et al.*, 2009; Palsaniya *et al.*, 2010). There is a deficit in the availability of green fodder, both quantitatively as well as qualitatively, which is further compounded during the lean and scarcity period (Kumar *et al.*, 2019). At present, India faces a net deficit of 30.65% green fodder and 11.85% dry forage (IGFRI Vision, 2050), that has been identified as one of the major reasons for poor livestock productivity (Anjum *et al.*, 2012; Kumar *et al.*, 2016a). Poor nutritional support during scarcity also caused adverse effects on the health of dairy animals which included, weight loss, poor fertility, and reproductive function, breeding cover, bovine population, and draft energy (Kumar *et al.*, 2019).

A diverse group of cultivated forage crops *viz.* Sorghum (*Sorghum bicolour* L.), pearl millet (*Pennisetum glaucum* L.), maize/corn (*Zea mays* L.), guinea grass (*Panicum maximum* Jacq.), dinanath grass (*Pennisetum pedicellatum* Trin.), oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), teosinte (*Euchlaena mexicana*), coix (*Coix lacryma* Jobi), cowpea (*Vigna unguiculata* L.), berseem (*Trifolium alexandrinum* L.), lucerne (*Medicago sativa* L.), cluster bean (*Cyamopsis tetragonoloba* L. Taub), horse gram (*Macrotyloma uniflorum* L.), ricebean (*Vigna umbellata*), lathyrus (*Lathyrus sativa*) and shaftal (*Trifolium resupinatum* L.) are grown in different parts of the country as per the ecological adaptability of the species (Kumar *et al.*, 2017a). List of non-legume crops cultivated for green fodders is given in Table 1. The area under fodder cultivation in India is going on shrinking due to increasing cultivation of cereals and cash crops and this is the major constraint in improving green fodder production.

Under these situations, the cultivation of maize for green fodder could have the potential to fulfill the nutritional requirements of livestock. Maize is the most studied plant for its high genetic diversity and is gaining demand as grain, animal feed fodder, and other industrial uses (López-Reyes *et al.*, 2015). It is cultivated in about 160 countries under diverse soil and climatic conditions with different management practices and contributes around 36% to global grain production. In India, maize is the third most important food crop with the production of 25 million tons, out of which 25% is used as human food, 49% as poultry feed, 12% as animal feed, remaining is used as industrial raw material and other purposes (Rani *et al.*, 2015). In addition to the above, the maize plant is also used as animal fodder for livestock throughout the world because it produces higher energy forage per unit area and time than other forage crops (Kumar *et al.*, 2016a). Among different non-leguminous forage crops, maize is considered ideal forage because it grows quickly, produces high palatable biomass, and helps to increase body weights and milk quality in cattle due to higher nutritional value (Chaudhary *et al.*, 2016; Iqbal *et al.*, 2006). Wadhwa *et al.* (2010) reported the highest organic matter (OM) and crude protein (CP) content while the lowest neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and hemicelluloses content in maize fodder as compared to the other forages.

Under a conventional feeding system, farmers practice daily cutting and carrying of fodders for feeding to the livestock. Daily cutting and carrying of fodder require more labor and also lead to an increase in the lignin content of fodder crops with maturity and advancement of age. Lignin is hard to digest and needs more energy affecting the net energy balance of the animals (Brar *et al.*, 2016). Shortage of feed and fodders led to the development of alternative fodder production systems involving conservation and storage methodologies for providing feed to livestock. Silage production has been seen to suffice all these factors which can help in round the year fodder availability for dairy animals. Among different fodder crops, corn is most suitable for silage making due to the high concentration of soluble sugars and starch in its forage (Hundal *et al.*, 2019), and corn silage is a major forage source for ruminants around the world (Wei *et al.*, 2018). Preservation of corn as silage, when the grains are in the milk stage, helps not only in providing nutritionally uniform feed but also spares land for the cultivation of other commercial crops (Brar *et al.*, 2017). Chaudhary *et al.*, (2014) reported that silage is as nutritious as green fodder and could replace conventional fodder without any ill-effect on the performance of dairy animals.

The production potential of forage maize and its preservation as silage can be altered with changes in agronomic practices. In this communication, different research findings to improve the production and preservation of quality maize fodder through agronomic interventions have been reviewed.

## Agronomy of maize cultivation for green fodder

### *Selection of cultivar*

The development and identification of novel planting materials is an important issue for harnessing the full potential of both cultivated and non-cultivated lands (Gosh *et al.*, 2016). There is a need to develop varieties with early bulkiness and growth rhythm matching physiology with concurrent weather variability for the higher rate of dry matter accumulation and longer leaf area duration in relation to climatic elements (Kumar *et al.*, 2013). In maize, most of the breeding programs were basically aimed at the improvement of grain yield without giving much importance to the yield and quality of its green fodder (Walli *et al.*, 1994). Now, the focus of research is shifted towards the development of an improved variety of maize with better herbage yield and nutritive value as fodder as well as silage under different agro-climatic conditions (Hundal *et al.*, 2019). Varieties of forage maize and their adaptation in different regions of the Indian sub-continent are given in Table 2.

Chaudhary *et al.* (2016) reported significantly higher plant height, number of leaves per plant, leaf length, leaf width, and green fodder yield per plant under variety J1006 in comparison to other normal and specialty corn cultivars. Taller plants of J1006 having broad leaves and thin stems were reported by Gupta *et al.* (2004). Kumar *et al.* (2016c) reported higher values of various growth parameters *viz.* plant height, number of leaves, leaf length, leaf width, and stem girth, under J1006 as compared to African Tall but the differences were statistically not significant. Kumar *et al.* (2017c) reported statistically similar green fodder yield and dry fodder yield of J 1006 and African Tall whereas J1006 accumulated higher crude protein than African tall.

The existing normal maize varieties are deficient in certain essential amino acids, particularly lysine, tryptophan, and threonine (Lauderdale, 2000) and the biological value of their protein is 40% that of milk (Bressani, 1991). The 'Quality Protein Maize (QPM)', in general, contains 55% more tryptophan, 30% more lysine, and 38% less leucine than that of normal maize (Vaswani *et al.*, 2015), and has the potential to produce quality

**Table 2 - Fodder maize varieties and their adaptation in Indian sub-continent**

| Variety | Salient features | Suitable region | Green fodder yield (t ha$^{-1}$) | References |
|---|---|---|---|---|
| African Tall | Resistant to stem borer, rust, leaf blight & downey mildew | All over India | 55-80 | Kumar *et al.*, 2012 |
| | | | -- | Gosh *et al.*, 2016; |
| | | | 53.71 | Kumar *et al.*, 2017c |
| PMC-6 (EC-3135) | Tolerant to stem borer, nematodes & leaf blight | North West zone | -- | Gosh *et al.*, 2016 |
| Pratap Makka | - | North West zone | 45-50 | Kumar *et al.*, 2012 |
| | | | -- | Gosh *et al.*, 2016; |
| Chari-6<br>J-1006 | -- | North West zone | 45-55<br>-<br>56.90 | Kumar *et al.*, 2012<br>Gosh *et al.*, 2016<br>Kumar *et al.*, 2017c |
| Vijai, Moti and Jawahar composite | -- | Entire country | 35-47 | Kumar *et al.*, 2012 |
| VL-54 | -- | Hilly areas | 35-45 | |
| APFM-8 | | South zone | 35-40 | |

**Table 3 - Weed control efficiency, weed index and green fodder yield of fodder maize**

| Treatment | Weed control efficiency (%) | | Weed Index (%) | | Green fodder yield (t $ha^{-1}$) | | References |
|---|---|---|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year | 1st year | 2nd year | |
| Atrazine 0.75 kg $ha^{-1}$ as pre emergence | 81.8 | 23.0 | 3.2 | 1.4 | 51.0 | 65.6 | Mukherjee *et al.*, 2019b |
| Atrazine 1.00 kg $ha^{-1}$ as pre emergence | 85.3 | 36.1 | 3.2 | 1.5 | 51.0 | 65.5 | Mukherjee *et al.*, 2019b |
| Atrazine 2.00 kg $ha^{-1}$ as pre emergence | 95.8 | 54.1 | 1.1 | 0.9 | 52.1 | 65.9 | Mukherjee *et al.*, 2019b |
| Atrazine + Pendimethaline (tank mix) as pre emergence | 4.4 | | 6.1 | | 72.2 | | Baldaniya *et al.*, 2018 |
| Atrazine + Topramezone tank mix at 20 DAS | 2.9 | | 3.6 | | 74.8 | | Baldaniya *et al.*, 2018 |
| Atrazine + Tembotrione tank mix at 20 DAS | 3.8 | | 4.0 | | 73.5 | | Baldaniya *et al.*, 2018 |
| Weed free (20 & 40 DAS) | 2.4 | | 4.0 | | 78.5 | | Baldaniya *et al.*, 2018 |

DAS- days after sowing

green fodder over normal maize because of its superior protein quality and digestibility (Graham *et al.*, 1980; Paes and Bicudo, 1995). Vaswani *et al.* (2015) reported that the chemical composition of QPM fodder was similar to that of normal maize varieties while its *in vitro* digestibility was better than normal varieties. Kumar *et al.* (2016b) reported the statistically similar green fodder yield of African Tall and J 1006 with quality protein maize cultivars (HQPM 1 and HQPM 4).

### Planting Methods and Density

Higher plant densities are favorable for forage crops than grain crops, however, forage crops also have a maximum limit of increase in plant population (Subrahmanya *et al.*, 2017). Forage maize responds in a different way to plant densities under different environmental conditions and cultural practices which influence forage yield and quality (Subrahmanya *et al.*, 2017). Optimum plant density in corn helped in the optimum use of moisture, nutrients, and solar radiation. (Farnham, 2001; Olson and Sander, 1988). Depending on growing conditions, optimal plant densities for the production of maize forage vary from 45,000 to 1,25,000 plants $ha^{-1}$(Baron *et al.*, 2006). Increases in maize forage yield with an increase in plant density depend upon a number of factors, including climatic conditions of the growing region, plant size, and leaf area (Haddadi and Mohseni, 2016). Subrahmanya *et al.* (2017) reported 19% higher green fodder yield by increasing the seed rate from 45 kg $ha^{-1}$ to 60 kg $ha^{-1}$. With further increase in seed rate up to 90 kg $ha^{-1}$, fodder yield remained at par. Kumar *et al.* (2016d) also reported higher green fodder yield at a seed rate of 60 kg $ha^{-1}$, which is at par with seed rates of 75 & 90 kg $ha^{-1}$. Mashreghi *et al.* (2014) reported that ridge planting with a planting density of 1,30,000 plants per hectare produces a higher green fodder yield. High plant densities resulted in an increased number of plants per unit area, higher plant height, and leaf area index which leads to better light absorption by flag leaves, thus high photosynthetic efficiency and resulted in higher forage yield (Tetio-Kagho and Gardner, 1988; Kumar *et al.*, 2015).

### Weed management

Weed infestation in maize imposes heavy competition to crops for growth factors and a loss of 30-40 % of applied nutrients was reported by Mundra *et al.* (2002). Among the dominant weed flora in fodder maize, Trianthema portulacastrum and *T. monogyna* recorded the highest values of absolute density (no. $m^{-2}$) and absolute frequency followed by *Cyperus esculentus, Digitaria ciliaris, Chenopodium album, Cleome viscosa* and *Coccinia grandis*, during late *Rabi* season and early summer season (Mukherjee *et al.*, 2019b). Arvadiya *et al.*(2012) reported *Echinochloa crus-galli* L. and *Cynodon dactylon* L. among monocots; *Cyperus rotundus* L. among sedges; and *Amaranthus viridis* L., *Digera arvensis* L., *Portulaca oleracea* L., *Alternanthera sessilis* L. and *Trianthema* spp. among dicots as predominant weed flora in maize. Some hardy weeds like *Brachiaria reptans*, *Acrachne racemosa*, *Commelina benghalensis* etc. posing serious problems in maize (Kaur *et al.*, 2016). Admixture of weeds with maize fodder during harvest like *Coccinia grandis* and *Trianthema*, reduces the palatability of green fodder and thus affects milk production of milch animals.

Weeds compete with crops for available resources resulting in yield loss, declining the quality of production, and also harboring many associated diseases caused by pathogens and pests. The maximum yield loss in maize was noticed when the weeds were not checked during a critical crop-weed competition period that depended upon the relative competitiveness of the crop and the weeds. Weed management during the early crop growth stage proved to be effective in reducing weed competition and increasing crop yields. Singh *et* *al.* (2016) reported that the critical period of crop-weed competition in spring maize is from 30 Days after sowing (DAS) to 60 DAS and that is very essential to keep crop weed free during this period by the adoption of weed control measures.

In fodder maize, management of weeds by hand weeding and mechanical weeding is very effective but sometimes it is not practicable due to moist soil and is also time and labour consuming. Under such conditions, chemical weed control has been proven very effective in reducing weed competition in the early stages and increasing green fodder yields. Mukherjee *et al.* (2019b) reported that the application of atrazine at the dose of 0.75 kg ha$^{-1}$ and above as pre-emergence, showed selectivity and effectiveness in controlling weeds in fodder maize (Table 3). However, atrazine residues were found from 0.008 to 0.531µg g$^{-1}$ in the green fodder maize at 60 days after application. Kaur *et al.* (2016) recorded the effective control of grass and broad-leaf weeds in maize by post-emergence application of non-selective herbicides paraquat at the dose of 500 g ha$^{-1}$ and glyphosate at the dose of 900 g ha$^{-1}$and 1800 g ha$^{-1}$ as a directed spray when the weeds were at 2-4 leaf stage.

Baldaniya *et al.* (2018) reported the lowest weed index and highest weed control efficiency (76.5%) under weed free {Hand weeding (HW) at 20 and 40 DAS} followed by the application of tank mix formulation of atrazine 0.5 kg ha$^{-1}$ + topramezone 0.025 kg ha$^{-1}$ at 20 DAS (73.9%). Green and dry fodder yield was significantly higher (785 q ha$^{-1}$ and 269 q ha$^{-1}$, respectively) with weed free (HW at 20 and 40 DAS) and it was statistically at par with application atrazine 0.5 kg ha$^{-1}$ + topramezone 0.025 kg ha$^{-1}$ tank mix at 20 DAS (748 q ha$^{-1}$ and 249 q ha$^{-1}$ respectively) (Table 3).

### *Weed management by corn-legume intercropping*

Intercropping cereals with legumes for forage production is a common practice in many parts of the world, applied to improve the quality of green fodder and to suppress weed growth due to the smothering effect of leguminous fodders, resulting in yield advantage in intercropping (Poggio, 2005). Intercropping is a cultural practice in which competition between crops and weeds is increased due to increasing the light interception by a weakly competitive crop resulting in the suppression of weeds (Baumann *et al.*, 2001). The lowest weed density in maize–bean and maize–cowpea intercrops as compared to sole crops was reported by Bilalis *et al.* (2010). This is due to a rapid increase in leaf area under maize–legume intercrops than with the sole crops, which leads to an increase in light interception by the crop canopy increasing their competitiveness

**Table 4 - Green fodder yield and quality of fodder maize under varying nutrient management**

| Nutrient application (kg ha$^{-1}$) | Green fodder yield (t ha$^{-1}$) | Crude Protein | Ether Extract | NDF | ADF | References |
|---|---|---|---|---|---|---|
| | | (%) | | | | |
| **N:P level** | | | | | | |
| 120:60 (100% RDF) | 59.82 | 9.54 | 1.72 | 61.03 | 31.79 | Subramanya *et al.*,2017 |
| 150:75 (125% RDF) | 63.70 | 10.20 | 1.84 | 60.30 | 31.41 | |
| 120:60 (100% RDF) | 57.31 | 9.68 | 2.31 | 67.38 | 44.82 | Kumar *et al.*, 2017b |
| 150:75 (125% RDF) | 59.17 | 10.12 | 2.41 | 66.96 | 44.53 | |
| 150:75 (150% RDF) | 59.86 | 10.32 | 2.45 | 66.66 | 44.33 | |
| **$ZnSO_4$ level** | | | | | | |
| 20 Kg ha$^{-1}$ as basel dose | 60.16 | 10.39 | 2.22 | 64.48 | 41.67 | Kumar *et al.*, 2017c |
| 0.5% two foliar spray at 30 and 45 DAS | 59.32 | 9.99 | 2.12 | 64.30 | 41.56 | |
| 10 Kg ha$^{-1}$ as basel dose + 0.5% one foliar spray at 30 DAS | 59.71 | 10.05 | 2.13 | 64.48 | 41.69 | |

NDF- neutral detergent fibre, ADF- acid detergent fibre, RDF- recommended dose of fertilizer, DAS- days after sowing against weeds. Prasad and Brook (2005) reported that during the early growth period of maize, its canopy is not able to intercept all incoming solar radiations, and the remaining radiation is captured by the intercrop growing under the maize. This resulted in blockage of the light from reaching the weeds thus suppressing their growth. Growing of maize and cowpea simultaneously in intercropping systems suppressed the weed growth more than monocultures (Mishra, 2019). Intercropping maize–cowpea in alternating ridges pattern resulted in more solar radiation intercepted by the canopy of the intercropping system and lowered the radiation available for weeds thus it helped in the reduction in weed biomass (Saudy, 2015). Less weed density by intercropping maize and legumes compared with the mono-cropped maize by blocking the availability of light for weeds was also reported by Bilalis *et al.* (2010).

Verma *et al.* (2015) reported higher weed control efficiency more than 80% and a weed index between 17.60 to 11.37% in maize and cowpea intercropping systems grown for quality fodder. The highest weed control efficiency of 90.6% under the maize + cowpea intercropping system followed by the maize + black gram intercropping system was also recorded by Selvakumar and Sundari (2006). Mukherjee *et al.* (2019a) reported that mixed cropping of maize (Variety '*African Tall*') + cowpea (Variety '*Bundel Lobia* 2') (50% seed rate of both the crops) reduced infestation of *Trianthema* spp. considerably due to the smothering effect of cowpea on weeds at 20-25 DAS and mixed cropping also provided balanced green fodder of cereal and legume combination to the cattle.

***Nutrient management***

Fertilizer application is one of the most important factors that directly influence fodder yield and quality. Forage dry matter yield of maize responded linearly to fertilizer rate (Kumar *et al.*, 2015). Maize is a heavy feeder and thus requires more amounts of nutrients to maintain a higher production level. Fertilizer management directly influences fodder yield, as the adequate supply of nutrients at each growth stage is really essential for good yield and quality of fodder maize (Nsanzabaganwa *et al.*, 2014; Subrahmanya *et al.*, 2017). Soil testing helps to detect the status of nutrients in the field before sowing and it is useful in the recommendation and application of the fertilizer according to the nutrient status of soil, which leads to improved quality and yield of green fodder. Nitrogen, phosphorus, and potassium (NPK) fertilization of maize is directly influencing its dry matter (DM) yield due to their effect on leaf area index, leaf area duration, and photosynthetic efficiency (Muchow, 1988). Nitrogen, a primary nutrient required by crop plants for their growth and development, plays an important role in vegetative growth and grain production in maize plants (Adediran and Banjoko, 1995; Shanti *et al.*, 1997). The application of nitrogenous fertilizers in maize crops increases its forage yield as well as improves its quality, especially its protein contents (Haque *et al.*, 2001), and improves its nutritive value by reducing ash and fiber contents (Baran, 1987).

Phosphorus is an integral part of nucleic acid, and is essential for cellular respiration and for metabolic activity. It is a primary nutrient for plant growth and development and its use along with nitrogen will help increase yield of maize (Safdar, 1997). An increase in plant height, number of leaves per plant, fodder yield, and quality by application of phosphorus was reported by Masood *et al.* (2011) and Khan *et al.* (2014). Subrahmanya *et al.* (2017) reported that in sandy clay loam soil, low in available nitrogen, medium in available phosphorus, and high in available potassium with neutral pH, application of nitrogen and phosphorus at the rate of 150:75 kg ha$^{-1}$ {125% recommended dose of fertilizer (RDF)} resulted in highest green fodder yield and dry matter yield. In green fodder, crude protein content and ether extract were higher whereas the level of NDF & ADF was lowest under 125% RDF (Table 4). Eltelib *et al.* (2006) and Singh *et al.* (2010) reported an increase in CP content of maize with an increase in nitrogen levels up to 150kg ha$^{-1}$.

Kumar *et al.* (2016d) reported that in soils low in available nitrogen, medium in available phosphorus, and high in available potash, the application of nitrogen and phosphorous at the rate of 180:90 kg ha$^{-1}$(150 % RDF) resulted in higher plant height, number of leaves per plant, leaf length, leaf width, stem girth and green fodder yield which is at par with 150:75 kg ha$^{-1}$ (125 % RDF). Application of 150 % RDF improved crude protein content, ether extract, and ash content while decreasing NDF, ADF, and acid detergent lignin (ADL) content and these parameters are at par with fodder maize fertilized with 125% (Kumar *et al.*, 2017b) (Table 4). This is due to the fact that the higher supply of nitrogen along with phosphorous resulted in higher protein synthesis and lowered the soluble carbohydrates which could be responsible for lower content of NDF, ADF, and ADL in fodder maize. Cox and Cherney (2001) reported the maximum dry matter yield of corn by fertilizing nitrogen150 kg ha$^{-1}$

Among different micro nutrients, zinc (Zn) plays an important role in quality fodder production. The occurrence of zinc deficiency in the soils resulted in its deficiency in food/fodder crops, and in animal and human nutrition (Nube and Voortman, 2006). Zn is involved in the immune system of animals, deficiency of which affects the health and milk production severely. The deficiency of zinc in soil will lead to poor yield as well as quality of fodder. Soil and foliar application of zinc sulphate have significant effect on fodder and nutrients yields, quality, and Zn dynamics of maize fodder. About 50% of Indian soils are deficient in Zn (Singh, 2011), causing low levels of Zn and yield losses in fodder crops and hence affecting the health of the livestock. Kumar *et al.* (2016c) reported that in soils deficient in available zinc, soil and foliar applied zinc sulphate had a significant effect on growth, green fodder, dry matter yield, and quality of maize fodder. They further noted that the highest green fodder yield, dry matter yield, and zinc concentration of maize was obtained with soil application $ZnSO_4$ at 20 kg ha$^{-1}$ which is at par with 10 kg ha$^{-1}$ $ZnSO_4$ as basal + 0.5% foliar spray at 30 DAS and also with two foliar spray of 0.5% $ZnSO_4$ at 30 and 45 DAS. This is due to the fact that soil application of zinc at the time of sowing, makes its early availability for crop plants for various metabolic activities for better growth and yield, while foliar application makes it available for higher photosynthetic activities at later stages.

Kumar *et al.*. (2017c) reported that maize zinc fertilization through soil and/or foliar spray can enhance not only fodder productivity but also the quality of fodder maize in North-Western region of India and elsewhere under similar agro-climatic conditions (Table 4). The optimum level of zinc in the plants enhances nitrogen uptake which further increases protein synthesis and promotes dry matter accumulation which improves the ash and ether content in corn fodder.

***Maize-Legume intercropping***

Forage corn provides high-energy content, but its crude protein content is relatively low. The inclusion of legumes along with cereals in green fodder has been reported to improve the forage quality, as legumes are rich in protein (Sharma *et al.*, 2007). Growing of non-leguminous fodders in a mixture with legumes has the potential to improve the palatability and digestibility of fodder (Kumar *et al.*, 2018). Forage legumes are rich sources of protein for dairy animals but their green fodder yield is very low in comparison with cereal forages (Iqbal *et al.*, 2015). Green fodder from corn is having high-energy content but low crude protein (CP) content and low biological value (Mlynár etal, 2004), which can be increased by incorporating it with protein-rich leguminous crop (Choukan, 1997). Corn-legume intercrops could noticeably increase forage productivity, enhance its quality, and also decrease requirements for protein supplements in comparison with corn monoculture (Baghdadi *et al.*, 2016).

Corn intercropping with legumes could increase forage quantity as well as quality and fulfill the protein requirement of dairy animals as compared with the corn monocultures (Liu *et al.*, 2006; Javanmard *et al.*, 2009). The objective behind the maize–forage legume intercropping is to efficiently utilize resources such as space, light, and nutrients and to increase the production of quality fodder. In order to get maximum green fodder yield from maize-grain legume intercropping, there should be proper spatial arrangements and planting rates of components in the intercropping system (Htet *et al.*, 2016).

Mishra (2019) reported that the crude protein and fiber content of maize fodder is 7-10% and 25-35 % respec-

**Table 5 - Effect of intercropping maize with cowpea and soybean on fodder yield and quality**

| Intercropping | | Quality Parameters (%) | | | | | References |
|---|---|---|---|---|---|---|---|
| | | DMD | NDF | ADF | WSC | CP | |
| **Maize : Cowpea** | **GFY (t ha$^{-1}$)** | | | | | | |
| 100:100 | 65.7 | 60.2 | 55.55 | 27.11 | 18.15 | 13.3 | Dahmardeh *et al.*, 2009 |
| 100:50 | 49.2 | 62.5 | 54.25 | 25.89 | 20.04 | 13.04 | |
| 50:100 | 46.3 | 57.8 | 57.95 | 29.88 | 18.16 | 13.62 | |
| 50:50 | 43.9 | 60.6 | 55.34 | 26.33 | 20.50 | 12.23 | |
| 100:0 | 48.8 | -- | -- | -- | -- | -- | Mishra, 2019 |
| 0:100 | 23.0 | -- | -- | -- | -- | -- | |
| 100:100 | 50.4 | -- | -- | -- | -- | -- | |
| **Maize : Soybean** | **DMY (t ha$^{-1}$)** | | | | | | |
| 100:0 | 14.77 | 63.68 | 57.65 | 36.26 | 26.96 | 10.83 | Baghdadi *et al.* (2016) |
| 75:25 | 14.68 | 65.66 | 57.62 | 36.48 | 26.98 | 12.75 | |
| 50:50 | 14.59 | 68.01 | 54.12 | 33.15 | 27.00 | 13.73 | |

GFY- green fodder yield, DMY- dry matter yield, DMD- dry matter digestibility, NDF- neutral detergent fibre, ADF- acid detergent fibre, WSC-water soluble carbohydrates, CP-crude protein tively and the crude protein content in cowpea fodder ranges between 16-21%. The Nutritive value of fresh biomass of cowpea (dry matter basis) is 12.5% digestible crude protein, 62.0 % in total digestible nutrients, 2.7 M cal $kg^{-1}$ of digestible energy, and 2.2 M cal $kg^{-1}$ metabolizable energy. Corn growing with legumes as intercropping, provides an efficient utilization of available resources and improves soil fertility through nitrogen fixation resulting in improved forage yield and quality. The fresh forage yield obtained from maize cowpea intercropping was 50.4 t $ha^{-1}$ in comparison to 48.8 t $ha^{-1}$ and 23.0 t $ha^{-1}$ from the sole maize and sole cowpea respectively (Table 5).Dahmardeh *et al.* (2009) reported the highest green fodder yield by sowing the maize and cowpea in the ratio of 100:100. Intercropping of maize-cowpea also resulted in an increase in forage quality (Table 5). Ginwal *et al.* (2019) reported the maximum green fodder yield and dry matter yield with intercropping of maize + cowpea (2:1) and maize + guar (2:1) intercropping combinations. The highest net income and benefit-cost ratio (B:C ratio) was also recorded with maize + cowpea (2:1) intercropping combination.Baghdadi *et al.* (2016) reported that intercropping of corn-soybean under different combination ratios increases CP content in green fodder as compared to the sole cropping of corn. They further reported higher DM yield of the corn-soybean intercropping with 50:50 combination ratio, which is at par with monoculture corn (Table 5). Protein yield and quality of forage resulted better under intercropping with 50:50 combination ratio than monoculture corn.

## Preservation of maize fodder as silage

Forage preservation as silage is a key element for round a year's supply of uniform level of high-quality forage for livestock farms. By this method, farmers are able to preserve forage when production is faster than the requirement of dairy animals, preventing the forage from becoming too mature and this procedure lets them utilize it during the lean period when the supply of green fodder is inefficient to meet demand at dairy animals. Thus, it helps in maintaining uniformity in the supply of quality fodder at dairy farms around the year.

Silage is the product of a series of processes by which cut forage of high moisture content is fermented to produce a stable feed that resists further breakdown in anaerobic storage (Kumar *et al.*, 2019). Silage preserves the nutrients in the original form and its nutritive value is as good as green fodders thus it is good for animal feeding as green fodder itself. Among different forage crops, maize is considered to be one of the best cereal fodder crops used for preservation as silage. Corn silage is preferred because of its relatively constant nutritive value, high yield, and higher water-soluble carbohydrates for fermentation to lactic acid (Darby and Lauer, 2002). In general, the superior nutritional quality of silage prepared from different cultivars of maize than their green fodder was reported by Chaudhary *et al.* (2016). There is a number of controllable and uncontrollable factors affecting the production of high-quality silage (Bernardes etal, 2018). During silage making, the palatability of fodder crop increases as hard stem on fermentation in silage becomes soft, this helps in easy digestion by dairy animals and the anti-quality components are either destroyed or lowered during silage fermentation (Chaudhary *et al.*, 2012). The production of quality silage depends upon a number of agronomic factors discussed below.

### *Selection of cultivar*

In order to get maximum yield of quality forage in minimum time, selection of cultivar is very important. Climatic conditions, especially growing period longevity affect cultivar selection directly (Ileri *et al.*, 2018). Hybrid selected for silage production should have high forage yield, high total digestibility, low fiber levels, highly digestible stover, and also high grain yield because grain is highly digestible and adds greatly to total dry matter (Jeff Hinen, 2006; Griffiths *et al*.., 2004). The maize hybrids grown for silage making are generally characterized by high yield potential with a large portion of the total dry matter contributed by the ears, valuable chemical components, and good digestibility (Zsubori *et al.*, 2013). An increase in the ratio of the ear in the plant dry matter is considered favorable, as grains in the ear, are the most energy rich part of plants and grains have the best digestibility (Tang *et al.*, 2006; Estrada-Flores *et al.*, 2006).

Brar *et al.* (2019a) tested three maize hybrids at the farmer's field for silage making (P1844, DOW2244, and P31Y45) and reported no significant difference among the hybrids with respect to dry matter, crude protein, NDF, ADL, pH, ammonia-N and buffering capacity. In the case of ADF, the minimum value was recorded for P31Y45, which was statistically at par with P1844 and significantly lower than DOW2244 (Table 6) and concluded that if the crop is managed and fodder is preserved scientifically, all cultivars are able to produce good quality forage leading to good quality silage. Brar *et al.* (2019b) studied the performance of three cultivars of maize (J1006, PMH 1, and P 1844) for silage making and reported significantly higher green fodder yield under hybrid P1844, which is at par with hybrid PMH 1 and significantly higher than composite variety J1006. Crude protein content was recorded significantly higher in silage prepared from PMH1 (10.5%) while

**Table 6 - Effect of cultivar on composition and fermentation pattern of silage**

| Cultivar | Dry matter | Crude protein | NDF | ADF | ADL | pH | References |
|---|---|---|---|---|---|---|---|
| | g 100g$^{-1}$ (%) | | | | | | |
| **P-1844** | 26.9 | 9.4 | 65.1 | 37.8 | 5.7 | 3.8 | Brar *et al.* 2019a |
| **DOW-2244** | 26.5 | 9.7 | 63.5 | 41.9 | 5.8 | 3.9 | |
| **P-31Y45** | 27.9 | 9.9 | 59.9 | 32.7 | 4.3 | 3.8 | |
| **P-1844** | 31.8 | 7.5 | 43.4 | 28.9 | -- | 4.0 | Brar *et al.* 2017 |
| **PAC-746** | 20.9 | 7.6 | 64.8 | 40.8 | -- | 3.5 | |
| **HM-4** | 25.2 | 9.2 | 69.9 | 42.4 | 4.8 | <4.0 | Chaudhary *et al.* 2016 |
| **DHM-117** | 22.3 | 6.3 | 67.4 | 38.9 | 4.7 | <4.0 | |
| **J-1006** | 22.0 | 8.0 | 65.9 | 36.6 | 3.1 | <4.0 | |
| **HQPM-5** | 23.1 | 7.5 | 64.9 | 38.0 | 3.9 | <4.0 | |
| **HSC-1** | 35.5 | 6.1 | 76.8 | 46.9 | 4.6 | <4.0 | |

NDF- neutral detergent fibre, ADF- acid detergent fibre, ADL- acid detergent lignin

dry matter content was recorded significantly higher in silage of P1844. Both hybrids are at par with respect to NDF and ADF content of their silage and significantly better than J1006.

### *Stage of crop harvesting*

Optimum time of harvest is the most important factor influencing the quality of corn silage. Early harvesting of crops resulted in lower dry matter yield per unit area while advancing crop maturity leads to a decrease in protein content, available energy, daily nutrient intake, and digestibility due to lower carbohydrate content and more lignin in green fodder. Corn should be harvested for silage when its moisture content is between 60-70% to ensure good storage and fermentation in silo (Jeff Hinen, 2006).

The milk line score (MLS) describes the maturity of grain in cob and is used as an indicator to determine the ideal stage of corn for harvesting for silage making (Griffiths *et al.*, 2004). The milk line is the division between the milky sugar in the developing kernel and the starch developed from those sugars (Jeff Hinen, 2006). It is visually inspected by breaking the ear of corn in half (Fig. 1). Notice the starch development from the top of the kernel towards its tip attached to the cob. It varies from 0 (no visible milk line at the tip of the kernel) to 5 (the milk line reaches the base of the kernel and a black or brown layer is formed across it. The milk line is used for a rough estimation of whole plant moisture level for harvest. Milk line score (MLS) of 2.5 or the milk line is halfway down the grain, is considered ideal stage to harvest maize for silage (Griffiths *et al.*, 2004; Jeff Hinen, 2006). They further reported that if harvesting is delayed to physiological maturity or MLS 5 or crop dry matter greater than 38 %, it is difficult to compact the chopped fodder resulting in poor fermentation and poor quality of silage. Brar *et al.* (2017) reported that delay in the harvesting of crops beyond 2.5 MLS resulted in an increase in NDF and ADF content in silage which could affect the digestibility of silage negatively.

Milk line is used for rough estimation of whole plant moisture level for harvest average time required for corn grain to reach ½ milk line from blister, late milk/dough and early dent stage was 25-35, 15-25 and 5-15 days respectively (Jeff Hinen, 2006).

### *Storage of green forage*

The quality of silage is also affected by the method of storage and period of ensiling (Brar *et al.*, 2019a). The time taken to fill the silo pit/bunker and adequate packing density of green fodder in the silo pit/bunker is also a very important factor in determining the quality of silage. Chaffed fodder should be filled in a silo pit as quickly as possible, as the longer filling time of chaffed fodder in a silo effect the maintained anaerobic conditions properly, which leads to increased aflatoxin levels in silage (Brar *et al.*, 2017). Wittenberg (2004) reported that the rapid elimination of oxygen from silo pits was critical for the prevention of storage molds. The subsequent aeration of silage can cause fungi to proliferate and if conditions are suitable, mycotoxin may be produced. Brar *et al.*, (2019a) reported the values of pH, dry matter, crude protein, NDF, ADF, ADL, ammonia-N as % of total N and buffering capacity of corn silage samples within the optimum range when silages were prepared by filling the silo pit within two days by harvesting crop mechanically using single row maize harvester and fodder was be ensiled for minimum 45 days.


**Fig. 1 - Progression of milk line in maize kernels.**

The density of green fodder storage in the bunker silos/silo pit affects the dry matter loss of green fodder during silage making. When silage density is low, more oxygen remains in the silo at the time of ensiling, leading to an increase in respiration losses (Piltz and Kaiser, 2004). DM loss in bunker silos after 180 days of storage was reduced from 20.2 % to 10 %, as the density of storage was increased from 10 to 22 lb DM $ft^{-3}$ (Ruppel *et al*., 1992). Aerobic bacteria utilize the trapped oxygen in the silo pit/bunker, and burn energy (DM) to grow and multiply resulting in reduced silage yield and quality. Dry matter loss through this process can be minimized by forcing as much oxygen out of the pile as possible before the bacteria can utilize it, by proper compaction of green fodder in silo pit/bunker. The packing density of 15 lb DM $ft^{-3}$ or greater is optimum to minimize dry matter loss (Jeff Hinen, 2006).

### *Corn-Legume mixture silage*

Among the non-leguminous fodder crops, corn is preferred for silage making due to its quick growing habit, higher yield, higher water-soluble carbohydrates for fermentation to lactic acid, and better nutritive value. The only limiting factor for its usage as the sole crop is its low crude protein (CP) content which is around 6-7% of its dry matter (DM). Legume crops, which can grow during summer, could be a good solution for dealing with this problem due to their high protein content, which is over 15% in many cases as reported by Kizilsimsek *et al*.(2020). They further reported that growing legumes in maize stands even at a low rate could improve silage quality. Intercropping legumes with maize

**Table 7 - Quality composition of maize- legume mixture silage**

| Silage Mixture | Dry matter | Crude protein | NDF | ADF | pH | References |
|---|---|---|---|---|---|---|
| | (%) | | | | | |
| **Maize-cowpea green fodder mixture** | | | | | | |
| 100:0 | 27.0 | 7.5 | 56.1 | 35.4 | 4.2 | Goyal and Tiwana, 2016 |
| 75:25 | 26.0 | 12.7 | 53.2 | 32.1 | 4.5 | |
| 50:50 | 25.8 | 12.4 | 52.0 | 28.1 | 5.0 | |
| **Intercropping** | | | | | | |
| Sole Maize | 31.4 | 6.16 | 54.8 | 28.8 | 3.8 | Kizilsimsek *et al*, 2020 |
| Maize + Mung Bean | 32.0 | 6.66 | 53.5 | 30.7 | 4.0 | |
| Maize + Climbing Bean | 30.3 | 7.15 | 51.9 | 30.1 | 3.9 | |
| Maize + Cowpea | 32.0 | 6.51 | 50.5 | 28.3 | 3.9 | |
| Maize + Soybean | 31.3 | 7.48 | 50.3 | 29.9 | 4.1 | |
| Maize | 30.1 | 8.4 | 40.1 | 22.2 | 4.1 | Htet *et al*, 2016 |
| Maize + Soybean | 34.3 | 12.7 | 39.7 | 21.6 | 4.7 | |

NDF- neutral detergent fibre, ADF- acid detergent fiber may not only improve yield and quality of feed but also limit the use of fertilizer, herbicides, and insecticides, which are heavily used in monoculture for high yield anxiety (Dawo *et al.*, 2007). Legumes are not generally used for silage making, as they are difficult to ensile due to their low dry matter, low water-soluble carbohydrates, and high buffering capacity which resist the lowering of pH during silage making (Ozturk *et al.*,2006) and results in the problem of effluent production (Bodine *et al.*,1983). Thus, to produce quality silage, an ensiling mixture of legumes with corn is a viable option to produce silage with optimum dry matter and protein content (Geren *et al.*, 2008). Crude protein content in silage is improved by intercropping corn with legumes for silage (Costa *et al.*, 2012; Prasad *et al.*, 2005; Contreras-Govea *et al.*, 2009; Zhu *et al.*, 2011).

Goyal and Tiwana (2016) studied the effect of ensiling green fodder mixture of corn with cowpea on the quality of silage and reported increased pH and $NH_3$-N production in silage mixture but also enhanced crude protein content in silage. However, mixing corn-cowpea at the ratio of 75:25 reported increased fermentation characteristics (Table 7).

Intercropping maize with soybean at different planting structures results in an increase in fresh fodder production and enhanced quality of silage with increased crude protein and decreased NDF and ADF concentrations in the silage (Htet *et al.*, 2016) (Table 7). Kizilsimsek *et al.*(2020) studied the effect of maize intercropped with some legumes on its silage feed quality and reported that silage pH was significantly decreased in all intercropping patterns, regardless of legume, indicating a sufficient fermentation occurred in the silo and, also resulted in an increase in crude protein (CP) content (Table 7). They further reported that intercropping maize with soybean increased dry matter recovery (DMR), dry matter intake (DMI), and relative feed value (RFV) compared to sole crop maize. The NDF values of intercropped maize were better than that of pure maize resulting in increases in DMI and concluded that growing legumes in maize stands even at a low rate could improve silage quality in terms of DMR, NDF content, digestible dry matter (DDM) rate, DMI and especially CP concentrations.

## Conclusions

The development and identification of suitable cultivars is an important step to be addressed for higher productivity of quality green fodder. Cultivars with early bulkiness, higher rate of dry matter accumulation, and longer leaf area duration, in relation to climatic elements, are suitable for maximizing green fodder productivity. Optimal plant density for maize forage helps to optimize the use of moisture, nutrients, and solar radiation; higher plant densities are favorable for forage crops than grain crops. Chemical weed control has proved to be very effective in reducing weed competition in the early stages for higher productivity of quality green fodder. Intercropping of maize with cowpea also reduced infestation of weeds considerably due to the smothering effect of cowpea on weeds; in addition, it provided balanced green fodder of cereal and legume combination to the cattle. Soil-test-based fertilizer application helps to plan the fertilizer application according to the nutrient status of the soil and it leads to improvement in the quality and yield of green fodder. Corn-legume intercrops improved forage productivity and quality as compared with corn monocultures. For quality silage making, the hybrid selected should have high forage yield, high total digestibility, low fiber levels and high grain yield to improve silage nutritional quality and digestibility. Corn should be harvested for silage when its moisture content is between 60-70% to ensure good fermentation in silos. Dry matter loss of silage due to the activity of aerobic bacteria can be reduced by expelling oxygen out of the silo pit/bunker by increasing the overall compaction density. Ensiling a mixture of legumes with corn resulted in production silage with optimum dry matter and protein content.

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