Agronomic Management Strategies Elevate Forage Sorghum Yield: A Review

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ABSTRACT
Forage sorghum is one of the most heat and drought resistant cereal forage having the potential to yield nutritious forage even during the months of extreme heat for dairy animals. It yields considerably higher biomass production with less use of fertilizers and irrigations. It can be grown in almost all types of soils and has the potential to tolerate soil toxicities without considerable reduction in green forage yield. But in Pakistan, per hectare green forage yield of sorghum is much less (about 13 tons per hectare in irrigated tracts) than the potential. Rainfed areas are producing even less green forage yield than irrigated tracts. A variety of factors reduce forage sorghum yield including selection of unsuitable forage sorghum cultivars, poor seed bed preparation, weeds and fewer use of fertilizers. Appropriate agronomic management strategies hold the key in bridging the gap between forage sorghum yield and potential. Appropriate variety selection, pre-sowing seed priming and seed treatment with fungicide, fine seed bed preparation, line sowing, balanced use of fertilizers at optimum time, irrigation management, insect-pest management and harvesting at 50% flowering stage are few of the strategies which can increase the forage sorghum yield to a great extent. Appropriate agronomic management strategies are bound to increase the forage sorghum yield as well as its quality attributes particularly protein contents. In this way, sustainable supply of green forage during summer reduces the drastic effects of forage shortage and ultimately milk production on sustainable basis can be ensured to cater the needs of rising population.

Key words: Agronomy, Dairy farming, Drip irrigation, Forages and fodders, Sorghum

INTRODUCTION
Intensive dairy farming is getting ground in Pakistan with each passing year. The prerequisite of intensive dairy farming industry is the availability of nutritious green forages in sufficient quantities throughout the year. The continuous supply of green forages ensures sustainable production of milk and meat. Green forages are considered to be beneficial in improving the productivity and performance of dairy animals due to their palatability [1]. Economics of production is another advantage associated with forages along with being the cheapest source of ruminant’s nutrition [2]. Forage sorghum (Sorghum bicolor L.) is a member of famous Poacea family. It is a tall, annual and warm season crop which has been cultivated in Indo-Pak subcontinent on wide scale mainly for lactating animals. Forage sorghum has attained a central place among summer forages because it has lot of benefits and advantages to offer to dairy farmers. It has the ability to tolerate soil toxicities much better than other crops. It thrives well in moderately saline and sodic soils [3]. It continues to grow well even in the wake of low to moderate drought stress due to better water use efficiency as well as drought resisting adaptations. Forage sorghum has been proved to be more economical than other cereal forages due to fewer requirements of irrigations and fertilizers. It is a short season forage which achieves its full bloom in 52-60 days after sowing if harvested at 50% flowering or heading stage [4]. It has the potential to give a reasonably high forage yield on per hectare basis. But without appropriate management, green forages yield decline and ultimately animals remain underfed. In Pakistan, yield of forage sorghum is only 13 t ha⁻¹[5, 6], which is much low than the potential of existing forage sorghum cultivars. The main culprit behind this poor forage yield is the use of outdated and obsolete crop production technology [7]. As Agronomic management strategies have the potential to increase forage sorghum yield and thus can go a long way in increasing the productivity of milch animals by ensuring the sustainable supply of feed resources particularly the green forages. Agronomy which is concerned with principles and practices of crop production and field management plays its due role in raising crops yield per unit of the area for food, feed, fuel and fiber [8, 9]. Appropriate agronomic management is vital to obtain the yields of crops according to their potential. If crops are poorly managed, let it be cereals, forages or pulses, genetic potential alone can never realize the dream of getting higher yield [10, 11]. Appropriate agronomic management has the potential to increase the profitability and can establish sorghum as an alternate crop of maize despite being a little low on nutritious scale as far as animal nutrition is concerned.

The aims and objectives of this review paper were to analyze different agronomic management practices prevalent in developing countries especially in Indo-Pak subcontinent for forage sorghum production. This review article also critically
assesses the advantages associated with modern agronomic strategies and brings into light their role in boosting forage sorghum yield so as to supply sufficient nutritious green forage to ruminants even during summer months.

**Sorghum origin and history**

The word sorghum is believed to be derived from Latin word *Syricum* which means grain of Syria. Africa has been recognized as the place of origin of sorghum from where it got spread to other parts of globe. It has been grown in Indo-Pak subcontinent even before the recorded history. Sorghum was introduced in China in thirteenth century, while seventeen century witnessed the introduction of this crop in USA from Africa [12, 13]. It is matter of immense interest that a forage sorghum variety known by the name of black amber or Chinese sugarcane was instrumental in establishing it as a green forage crop because before the introduction of this variety, sorghum cultivation was done for the purposes of getting grain and sugar for syrup preparation [14]. However now, there are five types of sorghum grown globally for different purposes. Sorghum is grown for grain purposes and varieties are dwarf or short staudered which attain the height of only 2.5-5 feet [15]. Forage sorghum is being cultivated from Americas to Africa and from Europe to Asia for ruminant nutrition. Forage sorghum varieties have been developed to accumulate more and more biomass and most of the varieties attain the height of 6-12 feet [16]. Forage sorghum varieties are coarse stemmed and are considered to be excellent for silage preparation. Sudan-grass is a fine stemmed forage crop and has been successfully grown as a short season forage crop globally. Sorghum-Sudan-grass is a hybrid of sorghum and Sudan-grass and is considered to be best for hay or silage preparation as well as for pastures. Sorghum-grass also known as Columbus grass or sorghum-alnum is also getting ground in many regions of Africa [12]. Thus it is fulfilling the dietary needs of hundreds of million people across the globe despite being a coarse grain. But the matter of fact is that forage sorghum is considered to be one of the most important forage crops for ruminant nutrition particularly in areas of extreme temperatures and water deficiency.

**Characteristics of forage sorghum**

Forage sorghum is annual, tall and short season summer forage crop which has the potential to provide nutritious green forage during peak of the summer months when other green forages cease to exist in field conditions. In growth habit and other general appearances, sorghum plant is closely related to maize. It has an erect stem which can reach to the height of 6-12 feet depending upon the variety, climate and adopted agronomic management strategies [17]. There are grooves on the stalk in between the nodes on one side and from each node on grooved side, a leaf gets emerges. The grooved nodes are present on the stalk in an alternate fashion which bears leaves on both sides of stalk. The culms/stalks of forage sorghum are usually juicy depending upon variety and agronomic management practices. Whenever there is not sufficient juice present in leaves, the midrib of leaves turn white due to the formation of air spaces. In latter stages, theses air space may be filled with juice and then become neutral instead of being white. The concentration and quantity of juice determines and influence the time needed to mature the forage crops as sweet sorghum needs more time to get mature for harvesting. Another factor which plays important role in the palatability of forage sorghum is the sweetness of juice which is independent of quantity of juice produced because a visibly dry looking stalk may be sweeter than a lush green juicy stalk. Sweet forage sorghum is likely to be consumed in more quantity by livestock than other types as far as green chop is concerned. However, if sorghum is going to be ensiled, then stalk sweetness becomes insignificant factor because most of the soluble sugars get converted to organic acids during the anaerobic fermentation process [18]. Unlike maize, in sorghum both male and female parts are present in the panicle at the end of culm. It has been found to be heat and drought resistant which have made this crop the best alternate in areas of extreme heat and deficient irrigation water.

**Green forage yield of sorghum in Indo-Pak subcontinent**

Sorghum as a forage crop has been grown in Indo-Pak subcontinent since pre-recorded history but with plant breeding and crop production technology development, it is gaining popularity among dairy farmers. As forage sorghum does not regrow like Sudan-grass or sorghum-Sudangrass, thus it is a single cut forage crop which has the potential to give plenty of green forage during summer months when other forages become scarce. In developed countries like USA, it is mostly grown as a silage crop. Silage is fermented feed prepared in anaerobic conditions in special structures called silos and may be fed to dairy animals during forage scarcity periods [3]. Sorghum fodder is also being grown to prepare hay which is the air dried fodder. In Pakistan, sorghum was considered to be the crop of rainfed areas, while irrigated tracts were thought to be the best places for maize cultivation. But climate change, economics of production and severely conflicting drought [19, 20] has made sorghum the best alternate of forage maize in irrigated areas as well. The current situation is that sorghum is gaining popularity among farmers and researchers have strived to introduce varieties which yield more biomass and are higher animal nutrition scale. But the matter of concern is that in irrigated tracts of India and Pakistan, sorghum is yielding only 13 t ha⁻¹ of green forage [4, 6], while the rainfed areas are yielding even fraction of irrigated forage sorghum yield. This is an alarming situation and food for thought for those who have the insight to foresee the rising agricultural water deficit, skyrocketing prices of farm inputs and rising number of milk animals which need to be adequately fed for sustainable production of milk and meat to ensure the food security of teeming millions. It is interesting to note that in USA, the green forage yield of sorghum is in the range of 21-30 tons per acre [12] depending upon the type of hybrid, climatic conditions and agronomic management practices. A variety of factors including variety, irrigation and fertilizers management and insect-pest management influence the green forage yield as well as quality parameters such as protein contents, fiber contents and ash contents. It is a matter of grave concern that in Pakistan, farmers have failed to achieve the forage sorghum yield according to genetic potential of prevalent cultivars. The main culprit behind this is poor management of crop particularly regarding irrigation, fertilizers [21] and insect-pest management. Appropriate agronomic management strategies have the potential to increase forage sorghum yield to a great extent. Though plant breeders need to strive for developing high yielding varieties but agronomists can only realize the actual potential of seeds by developing on farm agronomic
management strategies. Poor agronomic management also results in poor quality sorghum forage particularly protein contents. Thus it can said without any shadow of doubt that appropriate agronomic management strategies need to be taken into consideration as far as forage yield increasing strategies are concerned. Figure 1 showed that area under forage sorghum is decreasing, while the production has been increased over the years. Per hectare green forage yield of sorghum is also increasing (figure, 2), though the increase in yield is not much significant.

![Fig 1: Forage sorghum area (million hectares) and production (million tons) in Punjab, Pakistan [6].](image1)

**Agronomic management strategies to boost forage sorghum yield**

Researchers have described the greatest advantage associated with forage sorghum production is the diversity of management practices that can adopted according to the availability of facilities and local environment. Appropriate variety selection is the first and foremost step for successful crop production keeping in view the climate and other conditions. A variety of field experiments conducted under varying climatic and soil conditions have shown that hegari, JS-263, JS-2003 and F-9917 performed much better than other varieties in term of biomass production as well as quality aspects [4]. The germination of forage sorghum is reported to be adversely influenced by low soil temperature while rapid and robust germination was observed whenever the soil temperature was higher than 25°C. Thus in areas where there is low temperature, planting should be delayed until temperatures rises. As far Indo-Pak sub-continental climatic conditions are concerned, germination is rarely inhibited by low soil temperature because mostly sowing of forage sorghum is done from May to July during which temperature even rises to 45°C. As in Pakistan, there is a severe shortage of green forage during summer months, so forage sorghum planted in May has the potential to yield plenty of nutritious forage in mid of July and thus ruminant animals are not suffered long periods of forage dearth. However seed dormancy is the potential factor which may reduce the germination, while seed priming has been reported to increase the germination of cereals as well as other crops like forage legumes. Due to smaller seed size, sorghum seeds have less vigor and after emergence exhibit slow growth in contrast to forage maize thus seed priming may be an effective way and to overcome these problems [22]. After a suitable variety selection according to climatic conditions of the area, pre-sowing seed treatment with fungicide such as benlate, captan or vitavax and seed priming (hydro-priming, on-farm priming, halo priming, priming with other agents like growth hormones) [23] seed bed preparation is the next step which needs to be performed well for optimum germination and seedling establishment. Seed bed preparation involves first cost in the field and optimum seed bed preparation ensures better germination percentage. It has been concluded by a number of researchers after conducting field trials minimum tillage resulted in green forage yield that was at par with other conventional tillage practices which include 2-3 plowing followed by planking. Tillage practices can be reduced other by omitting any field operation or by combining two or more field operations such as seeding and fertilizer application simultaneously. Minimum tillage may result in better productivity due to less soil erosion and moisture loss because there is minimum soil disturbance whenever minimum tillage is followed. The concept of minimum tillage and zero tillage are particularly important for rainfed areas where the main concern is loss of soil moisture resulting from conventional tillage practices. Some researchers have demonstrated the fact that sorghum performs much better than maize in no-till system provided there are optimum conditions in the seed zone. Forage sorghum has the potential to give comparatively higher forage yield even when the seed bed is not so finer in complete contrast to maize which requires a much finer seed bed for optimum germination and seedling establishment. In arid or rainfed areas, disc or harrow may be avoided after plowing in order to keep wind and water erosion in check. Planting method is one of the most important crop production factors which determines and influence the germination percentage as well as seedling establishment. In advanced countries like USA, seed planters are used for sorghum sowing, but in indo-Pak subcontinent, broadcast method is the most prevalent sowing technique and single row hand drill is being used on very limited scale. Though plant to plant distance is not of much significance as far as forages sowing is concerned, but if line to line distance is also not maintained then the growth and development of plants are adversely affected in case of more narrow rows. Thus line sowing of cereal forages has the potential to increase the germination in first phase and growth.
and development of plants in later stages. Seed must be placed 2-4 inches deep in soil to provide optimum germination conditions to seeds. Too shallow or too deep planting of sorghum seeds is bound to decrease the germination percentage as well as reduce seedling establishment. If dairy industry is to develop on commercial basis, then the production of forages for dairy animals has to be ensured, otherwise underfed milch animals can never prove to be the winning horses. In order to ensure the mechanized sowing of forages, government as well as dairy industry stakeholders will have to shoulder the responsibility and invest in this context. After emergence at early growth stages, plants need nutrients particularly nitrogen in order to expedite vegetative growth along with phosphorous which acts as an energy currency in plants because energy rich compounds like ATP and NADPH contain phosphorous [8]. About all soils in Pakistan are deficient in nitrogen and phosphorous, while forage sorghum has been reported to respond well in the wake of potassium application. Appropriate fertility management is bound to increase crops growth and ultimately final yield and forage sorghum is no exception to it. As far as forage sorghum fertilizers requirement is concerned, researchers have suggested it similar to forage maize. However, even fewer fertilizers application has also been reported to produce biomass without significant decrease. Field experiments have demonstrated the fact that 5-7 tons of forage sorghum production requires about 18 kg of phosphorous and 58 kg of nitrogen. Other researchers have suggested 52 kg of nitrogen and 22 kg of P₂O₅ along with 20 kg of K₂O in order to get more than 20 tons of green forage yields per acre [3]. However, it has also been reported that sorghum can utilize nitrogen credits from previous crop more effectively than forage maize, thus fertility management should include previous crop nutrients credits. As far as small land holders in Indo-Pak subcontinent are concerned, then need to integrate organic and inorganic sources of plant nutrients in order to obtain higher forage sorghum yield. Farm yard manure (FYM) and poultry manure should be applied about a month prior to sowing in order to allow time for nitrogen release. Not only the quantity but method of fertilizers application influences the availability of nutrients to plants. Forage sorghum seeds are considered to be sensitive to fertilizers, thus side dressing (technique of placing fertilizers 2 inches deep and 2 inches away from crop seed) is suggested to avoid starter fertilizer injury or burn. Intercropping of forage sorghum with forage legumes such as cowpea, cluster bean and soybean has been reported to increase the total biomass production [24-30] from the same piece of land. Increased forage sorghum biomass production in sorghum-legumes intercropping systems has been attributed to the phenomenon of biological nitrogen fixation (BNF) which takes place in the nodules of legumes roots. Though insignificant amount of nitrogen is available to sorghum from legumes but as legumes can fulfill their most part of their nitrogen requirement thus more nitrogen may utilized by sorghum due to nitrogen saving by legumes. Weeds (any plant out of its place) prove to be the early competitors of forage sorghum and reduce the growth and development of the crop plants due to their ability to obtain water and nutrients more aggressively than crop plants. Until and unless, forage sorghum attains knee height, it is prone to moderate to severe damage by weeds so needs weed free environment at early growth stages. Once the crop gets established, it can throw weeds out of contest particularly due to the shading effect. The matter of fact is that there are comparatively less herbicides available for weeds of sorghum than maize, however farmers need to adopt and follow integrated weed management plan to control weeds according to availability of resources at their disposal. Proper cultivation in forage sorghum grown in rows may keep weeds under check and control. Being an allelopathic crop, sorghum excretes various types of allelochemical (secondary metabolites having positive or negative effects on organism living in immediate vicinity) [30-36], which prevent the attack of a variety of insect-pest. Rarely root-rot, stem-rot, charcoal rot invade forage sorghum in Indo-Pak subcontinent. Irrigation management strategies not only save water but also increase green forage yield per unit area with fewer use of water. Sorghum has the potential to grow well even in the wake water deficiency while maize start leaf rolling at even mild water deficiency. When drought prolongs, sorghum becomes dormant until and unless drought stress is relieved and starts to regain turgidity when water becomes available. Though drip irrigation (technique in which water is dripped in the root zone of crop plants with the help pipes and a pumping system) is a costly technique, but once installed, it can save water to a great extent. Forage Sorghum contains higher contents of HCN at young stages, however if harvesting is done at 50% flowering stage, HCN contents decrease to a great extent and green forage may be fed to each and every class of livestock. Plant breeding has increased the potential of forage sorghum to provide more protein (9.3-9.5%) by reducing lignin contents (4.4%) and appropriate agronomic management strategies has realized this dream.

Table 1: Quality parameters (%) of sorghum, BMR sorghum and maize [12]

<table>
<thead>
<tr>
<th>Crop</th>
<th>CP (%)</th>
<th>ADF (%)</th>
<th>NDF (%)</th>
<th>Lignin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Sorghum</td>
<td>8-8.3</td>
<td>29.8</td>
<td>49.1</td>
<td>4.4</td>
</tr>
<tr>
<td>BMR Sorghum</td>
<td>9.3-9.5</td>
<td>27.5</td>
<td>45.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Maize</td>
<td>9.5</td>
<td>23.9</td>
<td>41.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Prevalent Sorghum cultivars in Indo-Pak subcontinent
BMR= Brown mid rib sorghum
CP= Crude protein
ADF= Acid detergent fiber
NDF= Neutral detergent fiber

CONCLUSION
Forage sorghum being the most heat and drought resistant cereal forage has the potential to provide nutritious green forage to dairy animals during months of extreme heat when other green forages become deficient. However, it has failed to attract the attention of farmers in irrigated tracts of Pakistan and researchers and this has resulted in much less green forage production and yield of sorghum on per hectare basis. Appropriate agronomic management strategies have the potential to increase the green forage yield of sorghum and that too with the use of fewer resources. Agronomic management strategies adopted from seed sowing till harvesting ultimately
determine the forage yield as well quality parameters. Selection of suitable cultivar according to the climatic conditions of the area and pre-sowing seed treatment with fungicide increase the chances of successful crop production. Seed priming has also potential to increase the germination as well as seedling establishment of forage sorghum. Optimum seed bed preparation and line sowing has also been reported to increase the green forage yield of sorghum. Integrated use of organic and inorganic sources of fertilizers not only increase forage yield but also in an economical way. Inorganic fertilizers need to be side dressed to avoid the starter fertilizer injury. Integrated insect pest management (IPM) also needs to be adopted for raising forage sorghum yield. Harvesting of forage sorghum at 50% flowering stage yields the best quality forage with minimum HCN contents. Thus appropriate agronomic management strategies have the potential to increase the green forage yield of sorghum to a great extent and need of hour is to make farmers aware of latest agronomic practices. Only by adopting site specific and latest agronomic management strategies, sustainable supply of green forage for dairy animals can be ensured.

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