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Full Length Research Paper

Flower and pod abortion and its implication to seed production in *Gliricidia sepium* (Jacq.) Walp

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***Gliricidia sepium* is an important species in tropical agroforestry systems where it is grown as a multipurpose tree species. The species is generally propagated from seed and stem cuttings. Establishment from seed is hampered by seed shortages as seed yields are very low on most sites. Gliricidia flowers profusely but pod and seed set are very low and this is attributed to high levels of flower and pod abortion. The objective of this study was to determine the level of flower and pod abortion in gliricidia, and contrast it with other related forest tree species. Sixty trees were randomly selected in two seedling seed orchards located at two sites: 30 trees each at Makoka and Chitedze Research Stations. Five racemes (with floral buds) per tree were randomly selected and tagged. The floral buds were monitored every two days to record the number of opened flowers and developing pods until all the tagged floral buds had opened and developed into mature pods or aborted. A high proportion (93%) of the trees completely aborted all their reproductive structures at Chitedze compared to only 6% at Makoka, making the former site less favourable for seed production compared to the latter. Overall, less than 3% of the flowers initiated in gliricidia produced pods, the rest were dropped. The observed level of abortion is not unusual as it is largely comparable to other related forest tree species of the Fabaceae family. Seed producers could improve seed yields in gliricidia by establishing seed orchards on appropriate sites and also using some seed sources with inherently high seed yield potential.**

Keywords: Agroforestry, flower and fruit abscission, pollination, seed yield.

INTRODUCTION

Since ancient times *Gliricidia sepium* has been an important tree species in tropical and subtropical agroforestry systems. 'Cacahuanantl' and 'madre de cacao', which are the Aztec and Spanish names for gliricidia literally meaning "mother of cacao" (Kass *et al*., 1997) indicate its long history of use as shade for cacao since the domestication of the later. It is now widely planted as an intercrop with maize to improve soil fertility (Kwesiga et al., 2003), for fodder (Stewart and Simons, 1994), shade, fuelwood and boundary marking among the major uses in the tropical and subtropical countries (Elevitch and Francis, 2006).

In Malawi, gliricidia is established predominantly using seeds. Although the species can easily be established from stem cuttings (Glover, 1989), such a practice has not been widely promoted in Malawi. The species is a shy seeder (Stewart and Simons, 1994) although it flowers profusely on most sites. Most of the flowers are however aborted resulting in low seed yield. The problem significantly increases the cost of seed production and has been identified as one of the constraints to adoption of this species in agroforestry systems.

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Abscission of flower buds, flowers, and fruits is an important yield-limiting factor in many field crops and tree crops. Stephenson (1981) conducted a comprehensive review of literature on the factors that cause flower, fruit and seed abortion for a large number of taxonomically diverse species that commonly abscise a large portion of their flowers and developing fruits. The conclusion was that lack of pollination, limited photoassimilates, adverse weather conditions, moisture stress and predation were some of the major factors contributing to abortion.

Time of flowering and fruiting in gliricidia varies with climate, elevation and dry season duration. In its natural range in Mexico and Central America (latitudes 7-25°N), the climate is sub-humid with 5 months of dry season from December to April (Hughes, 1987; Simons, 1996). Trees lose their leaves early in the dry season between December and January, flower and fruit during the later part of the same dry season, January to March, before leafing out (Hughes 1987; Simons, 1996; Elevitch and Francis, 2006). In Malawi and most of southern Africa, gliricidia loses its leaves during the cool dry season (June-July) and flowers at the start of the warm dry season (August to September) and the pods mature in September to October with the trees still leafless. It is believed that floral initiation may be related to short days, dry season moisture stress or deciduousness (Hughes, 1987; Simons, 1996). The species is an obligate out-breeder and therefore will produce fruits only after cross-pollination (Simons, 1996; Kiill and Drumond, 2001).

Despite the importance of gliricidia in smallholder agroforestry systems and the challenges of seed availability, few attempts have been made to investigate the causes of the observed low seed yield potential of seed orchards in Malawi. Understanding the level of flower and fruit abortion, its causes is important to scientists interested in tree improvement and seed production. There are a few important questions that need to be answered with regards to gliricidia flowering and seed production. What is the level of abortion in gliricidia? Is the level of abortion unusual compared to other related species? What is the effect of site on flower and pod abscission?

MATERIAL AND METHODS

The study was conducted in two seedling seed orchards of *G. sepium*: a 13- year old at Makoka Agricultural Research Station (latitude 15°30'S, longitude 35°15'E, elevation 1030m a.s.l.) and an eight-year old at Chitedze Agricultural Research Station (latitude 13°85′S, longitude 33°38′E, elevation 1146 m a.s.l). Rainfall at Makoka and Chitedze averages 982mm and 892 mm per annum respectively. For both sites, 85% of the rainfall falls between November and March. There are three distinct seasons: mid-November to early April is the hot wet season, May to mid-August is a cool dry season, mid-August to mid-November is the hot dry season (Fig. 1). Soils at Chitedze are the Ferruginous Latosol while those at Makoka are the Ferric Lixisol.

Thirty trees were randomly selected in each seed orchard. Five racemes (with floral buds) per tree were randomly selected and tagged on the easily accessible branches of each tree. The number of floral buds on each raceme were counted and recorded. The number of floral buds tagged per tree ranged between 49 and 137 at Makoka, and between 87 and 238 at Chitedze. Thereafter, the same racemes were monitored every two days, to record presence or absence of any of the reproductive structures (floral buds, open flowers and developing pods). The final count of mature pods was made at harvest and the seeds per pod were also determined.

Data for the number of floral buds, opened flowers and pods present over time was plotted against time to track the changes in their numbers to ascertain the point of abortion. The abortion rate was calculated as:

Abortion rate = $(N_{\text{floral buds}} - N_{\text{pods}}) / N_{\text{floral buds}} * 100$,

Where:

N_{pods} is the number of pods at harvest,
$N_{\text{floral bud}}$ is the number of floral buds tagged at the start of the experiment.

RESULTS

The flowering of gliricidia at the two sites was profuse as in most of the previous years. Although the mean number of floral buds tagged per tree at Makoka was 95, the number of flowers that opened peaked at 76, while that of pods peaked at just over 15 (Fig 2a). From a mean of 146 tagged flower buds per tree at Chitedze, the number of open flowers only reached a peak of 24 while the number of pods peaked at three (Fig. 2b). Most of the abortion occurred between floral bud and open flower phase at Chitedze while at Makoka it occurred during the open flower (receptive) phase (Fig. 2).

A plot of the changes in all the reproductive structures (floral buds, flowers and pods) combined showed a clear trend in the process of abortion (Fig. 3). The abortion at Makoka was initially gradual in the first three weeks becoming rapid in the fourth week. In comparison, the abortion at Chitedze began early and was rapid but steady. By the end of the 2nd week, abortion of the reproductive structures had already reached more than 70% at Chitedze but was only about 1% at Makoka.

Besides differences in the rate of abortion between the two sites, there were significantly more trees that had complete abortion of the reproductive structures at Chitedze compared to Makoka: 93% versus 6.7% (Table

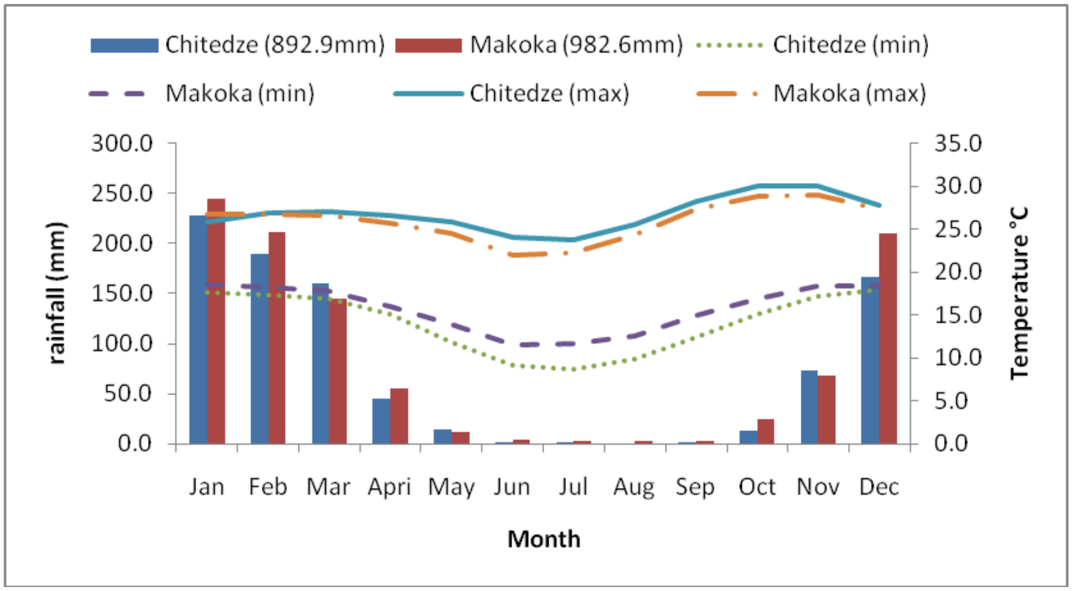
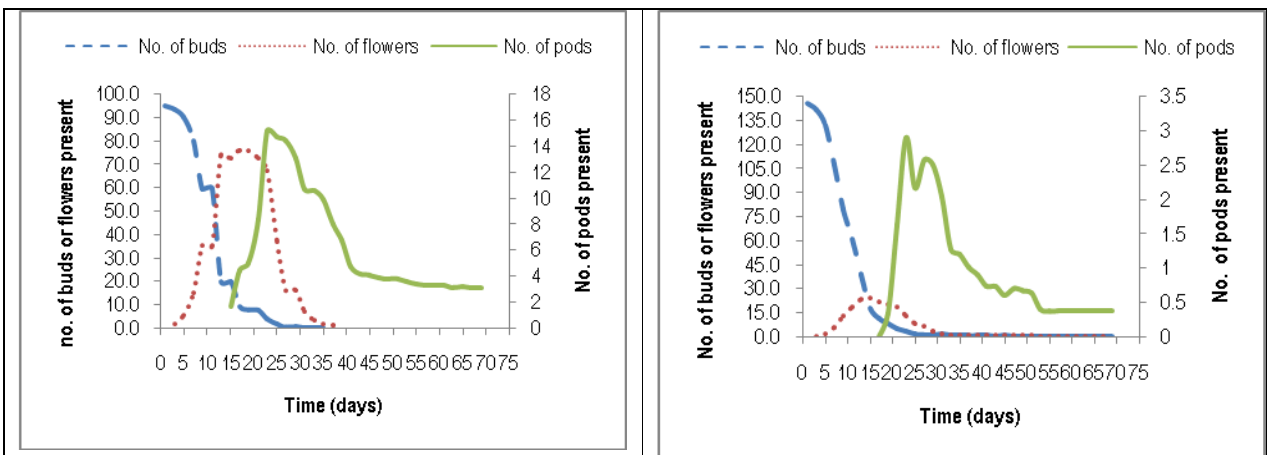


Figure 1. Mean annual rainfall and mean maximum and minimum temperatures at Chitedze and Makoka Research Stations.



(a) (b)

Figure 2. Trends in floral bud, flower and pod abscission in *G. sepium* at Makoka (a) and Chitedze (b).

1). Overall, the percentage of flowers that set fruit was only 0.3% at Chitedze and was significantly lower than the 3.2% at Makoka. The number of seeds per pod ranged between 3.3 and 8.7 with a mean of 6.1 seeds at Makoka (Table 1). The seeds per pod were not counted on the other site.

DISCUSSION AND CONCLUSIONS

Gliricidia belongs to the Fabaceae family and Papilionoideae subfamily. Compared to its relatives, the level of abortion in gliricidia found in this study is not unusual as it is largely comparable to other related forest tree species (Table 2). Other studies (Rockwood, 1973; Simons, 1996) have also shown that some gliricidia trees drop all their flowers and pods, which is consistent with the results of the present study. Studies in other forest trees (Burd, 1998; Suitor *et al*., 2010); horticultural tree species (Ruiz *et al*. 2001) and field crops (Kokubun, 2011) have all revealed high rates of abortion of flowers and fruits. Observations across several plant taxa have shown that many plants produce more flowers than would finally develop into mature fruit (Taylor and Obendorf, 2001;

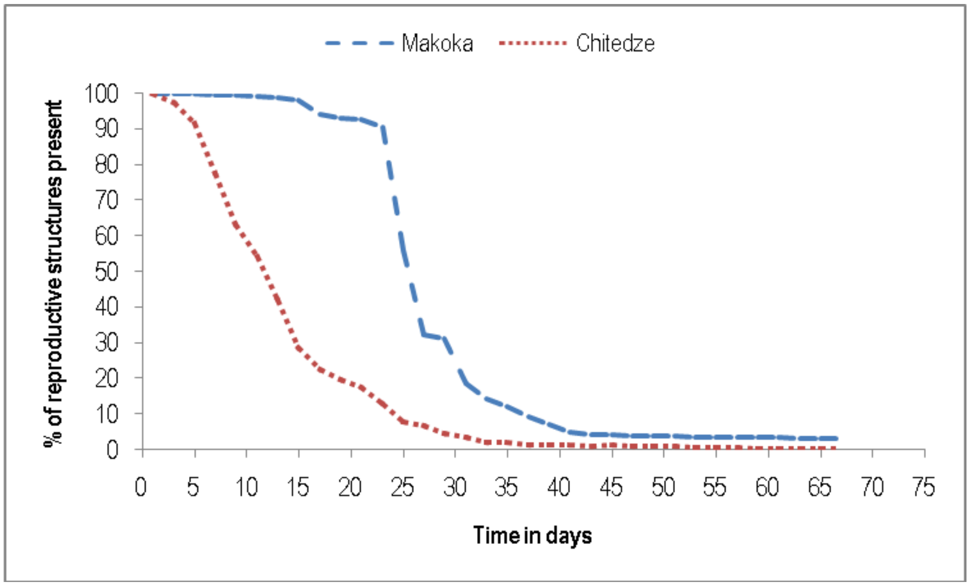


Figure 3. Trend in the abortion of reproductive structures (buds, flowers and pods) at two sites.

Table 1. Abortion of reproductive structures in *G. sepium* at two sites.

Traits	**Makoka**		**Chitedze**	
	range	Mean	range	Mean
No. of floral buds tagged per tree at initiation	49 to 137	95.1	87 to 238	145.7
No. of mature pods (from the tagged flower) per tree	0 to 7.0	3.2	0 to 6.0	0.3
Flower abortion/abscission rate per tree (%)	93 to 100	96.8	94 to 100	99.7
Percent of trees with 100% flower/pod abortion		6.7		93.1
No. of seeds per pod	3.3 to 8.7	6.1	na	na

Na = not assessed

Table 2. Abortion rates in gliricidia compared to selected species in the Fabaceae family.

species	**subfamily**	**% of female flowers that mature into fruits**
Cassia grandis	Caesalpinoideae	0.2 - 0.5
Hymenaea courbaril	Caesalpinoideae	0 - 10
Prosopis chilensis	Mimosoideae	0 - 0.2
P. flexuosa	Mimosoideae	0 - 1.3
P. velutina	Mimosoideae	0.1 - 2.5
Lupinus texensis	Papilionoideae	2.4
*Gliricidia sepium**	Papilionoideae	0.3 – 3.2

Source: Stephenson (1981) and this study*

Wesselingh, 2007; Suitor et al., 2010). This is particularly common in allogamous species (Stephenson, 1981). Gliricidia is an allogamous species and only produces fruits after cross-pollination (Simons, 1996; Kiill and Drumond, 2001).

The cause of the observed high abortion rate in gliricidia is a question of conjecture as this was not part of this study. Causes of flower and fruit abortion vary with species and include absence of compatible pollen especially with species that are obligate out-breeders

(Kiill and Drumond, 2001); availability of photo-assimilates (Stephenson, 1981; Burd, 1998); excess pollen landing on the pistillate (McGranahan *et al*., 1994); high temperatures (Guilioni *et al*., 1997); water stress (Muhl *et al*., 2013); predation (Arista *et al*., 1999) and insufficient pollen grains to fertilise all the ovules (Heithaus *et al*., 1982; Quesada *et al*., 2001). Gliricidia is known to attract few insect visitors because many of the potential pollinators have difficulty in prising apart the keel petals to reach the nectar on the stigma (Simons, 1996). This could potentially lead to insufficient pollen landing on the stigma resulting in abortion of the unfertilised flower. Elliott and Irwin (2009) hypothesised that some species produce abundant flowers to help attract more pollinators to the flowers and improve the chances of pollination.

In Southern Africa, another potential factor that may cause flower and pod abortion in gliricidia could be inadequate assimilates as the species flowers and fruits in the middle of the dry season when the trees are leafless. This means that the process of floral bud initiation, flower and pod development is dependent on stored resources. The contribution of stored assimilates to the flowering and fruiting effort has been demonstrated in other species (Goldschmidt and Golomb, 1982).

Differences in the timing, extent and rate of flower and fruit abortion observed between the two sites in this study indicated that environmental factors could also have a role in flower and pod abscission. Because this study was conducted on a limited number of sites and seasons, further studies covering more sites and seasons could help to identify the environmental factors that influence flower and pod abortion in gliricidia. Besides choosing a site to improve seed set, seed producers can also select the right seed source as large differences in seed yield between provenances of gliricidia have been reported (Simons, 1996). For example, seed yield of Monterrico provenance was found to be more than two times that of Belen Rivas (Simons, 1996).

The major findings of this study were that less than 3% of the flowers initiated in gliricidia form pods, the rest are aborted. The observed level of abortion is not unusual as it is comparable to other forest tree species of the Fabaceae family and Papilionoideae subfamily to which gliricidia belongs. The level of abortion in gliricidia depended on site and some trees completely aborted all their flowers and pods. Seed producers could improve seed yields by selecting appropriate sites and using the right seed sources as other studies have shown significant differences in seed yield potential of different seed sources. Multi-location and multi-season studies are required to identify sites and climatic factors that could be exploited to improve seed yield of gliricidia.

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