SMALL GRAIN CEREAL–CLOVER MIXTURES FOR FORAGE PRODUCTION

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ABSTRACT. Fresh forages are the cheapest source of animal feed in the world. Small grain cereals (SGC) are the most commonly used fresh forages or ensiled forage. Clovers are the perennial legumes that offer quality forage but their initial dry matter (DM) yield is low. Usually, SGC and clover are sown in mixtures to draw benefits from greater Cut-1 DM yield of cereals and biological nitrogen (N) fixation of clovers. However, mixtures are difficult to manage, compared to monoculture owing to differences in their growth pattern, temporal, spatial and physical requirements. In this review, SGC-clover mixtures are analyzed for their potential herbage DM yield and quality of the produce. Effect of various management factors on the productivity of forage mixtures are well documented. Decisions in managing mixtures, like choice of cereal and cutting time and how they affect the value of the final produce is reviewed. Besides decision, effect of relative proportion and spatial arrangement of intercrops is also deliberated. Special attention is paid to the competition between SGC and clovers and its impact on clover suppression in mixture. At the end conclusions are drawn to optimize production from mixtures.

Keywords: clover regrowth; competition; cutting time; relative proportion; spatial arrangement.

INTRODUCTION

Intercropping is aimed at higher crop productivity besides other associated advantages, i.e. greater yield stability between different and diverse climatic conditions (Deak et al., 2009), lower incidence of pests, higher nutritional value of mixed diets, improved water use efficiency, yield advantage in subsequent crops,
reduced soil erosion because of greater ground cover and higher land use efficiency (Anil et al., 1998). Mixed cropping is based on the ecological principle of biodiversity and is assumed to have potential benefits in productivity, resilience to disruption and ecological sustainability (Vandermeer, 1989).

Mixture of small grain cereals, the name given owing to their short plant structure, like wheat, oat, barley, rye and triticale with clovers have been exploited in many areas of the world. This mixed sowing system is advocated for its potential of providing shield against high production cost along with better distribution of labor and equipment. Foremost objective in sowing cereal-clover mixture for forage is to have higher green/DM yields of better quality as a result of clover inclusion. Proposed benefits from this mix sowing arise from differences of both species in plant phenology, growth habit, root system and exploitation of different soil depths for nutrients.

Apart from yield and quality advantages, cereal-clover mixtures provide forage throughout the season. This aspect of cereal-clover mixture lie with the clover’s potential of multiple cuttings, especially when climate and moisture dynamics prolong the growing season and exceeds cutting date of cereal in mixture. First cut in SGC-clover system with bulk of cereal share may be preserved as silage while subsequent cuts of clover be used as fresh forage (Ross et al. 2004a).

Theories and approaches in mixtures greatly differ from that of monocultures (Ross et al., 2004a), as both of the intercrops in SGC-Clover mixtures interact with each other on time and space scale. Most of the agronomic practices aimed at optimizing tradeoffs between DM yield and forage quality. However, success of this intercropping system depends upon many factors like species of intercrops, relative seeding proportions, cutting time (Eskandari et al., 2009), spatial arrangements and period of their co-existence etc.

Literature reticence on the subject urged the authors to review diffused literature to concisely amass salient outcomes of different studies addressing various management aspects of mixtures. In this review, productivity is discussed in view of DM production and forage quality improvement. Role of cereal choice in success of mixture and cutting time of the mixtures are also deliberated. This article further highlights the dynamics of interaction between SGC and clover and its potential impact on final produce.

Choice of cereal

Selection of suitable SGC to mix with clover is very crucial in the success of intercropping system as choice of cereal affects the performance of intercrop in mixture (Ross et al., 2004a,b). Cereals vary for growth habit, tolerance to stress, morphology of leaves and roots, biomass accumulation pattern, intrinsic yield ability and nutritional...
value (Collins and Rhodes, 1990), which provide the option for the farmers to select the cereal crop to meet their own objectives. A general comparison of small grain cereals are depicted in Table 1 (adapted from Braunwart et al., 2001).

Table 1 - A character comparison of small grain cereals (number of stars indicate character strength of the cereal)

<table>
<thead>
<tr>
<th>Cereal</th>
<th>Early growth</th>
<th>High grain yield</th>
<th>Tolerance to disease</th>
<th>Tolerance to sodic soil</th>
<th>Tolerance to drought</th>
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<tbody>
<tr>
<td>Wheat</td>
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<td>Rye</td>
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<td>Barley</td>
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A compatible cereal-legume mixture assures clover contents in mixture large enough to optimize the potential benefits of N-fixation and mixture quality improvement (Rhodes et al., 1994). Even the cereal cultivars have differences in their effects on clover stand, clover yield and total biomass production (Holland and Brummer, 1999). Semi-dwarf or short stature cultivars are more suitable for mixing with berseem clovers due to less lodging, compared to conventional-stature cultivars (Simmons et al., 1995) and offers less competition to companion crop (Simmons et al., 1995; Ross et al., 2004a,b). Barley is more competitive than other cereals and if a more competitive cereal is to be used then fertilizer rate should be kept low as higher fertilizer rate tends to increase competitive ability of cereals (Annichiario and Tomasoni, 2010) and lower the N fixation of clovers (Hogh-Jensen and Schjoerring, 1997). Earlier maturity of cereal provides longer regrowth periods for clover, that provides higher regrowth (Ross et al., 2004b). Barley reaches to its heading and subsequent growth stages earlier than oat, wheat and ryegrass and produce greater DM yield (Ross et al., 2003; Ross et al., 2004a; Contreras-Govea and Albrecht, 2005). However, inclusion of early maturing cereal (barley) in mixture with clover reduces the initial forage yield of mixture, compared to late maturing cereal like oat (Ross et al., 2004a; Thompson et al., 1992; Juskiw et al., 2000). In situations where objective is to have higher Cut-1 DM yields oat-clover mixture should be the choice as it yields greater Cut-1 DM yield than barley-clover (Jedel and Salmon, 1994; Ross et al., 2004b) and ryegrass-clover (Wickham et al., 2007) mixtures owing to more tiller mean weight and taller oat plants (Ross et al., 2004a). However, considering total seasonal production, barley-clover mixture is
more advantageous owing to early maturity that provides more regrowth period for clover and higher CP contents of barley, compared to other cereals.

**Dry matter production**

Cereals yield more than clover monocultures and cereal-clover binary mixtures prior to Cut-1 (Contreras-Govea and Albrecht, 2005; Ross et al., 2005a; Shoaib et al., 2013; Andrzejewska et al., 2014), yet some researchers found that mixtures yields equal or greater DM yield than component sole corps (Vasilakoglou and Dhima, 2008; Salama, 2015). However, total seasonal DM production from SGC-clover mixture exceeds both cereal and legume monocultures due to cereal contribution in Cut-1 and subsequent multiple cutting of clover (Shoaib et al., 2013; Andrzejewska et al., 2014). Cereals dominate early season DM while clover provides the production stability in mixture (Matusinsky and Hrabe, 2003) and improves the forage quality (Ross et al., 2005a,b). There is a negative relationship between Cut-1 cereal herbage DM yield and regrowth clover herbage DM yield (Holland and Brummer, 1999; Ross et al., 2004b).

Slow establishment of clover is one of the reasons of its negligible Cut-1 DM yield in mixture with cereals (Ross et al., 2005a,b). According to Martiniello (1999), average legume % in the mixtures of clovers (berseem, crimson and persian) with barley and Italian ryegrass was 22 and 21%, respectively. Similarly, Ross et al. (2005b) found berseem % in mixture with oat to be 21-43% under varying seeding ratios of oat. In Faisalabad conditions, berseem % in mixture with 25% oat seeding ratio was 16.94% and 13.70% of total Cut-1 DM yield at booting and heading stage of oat, respectively (Shoaib et al., 2013). However, efforts should be made to maximize the clover contents in Cut-1 DM yield as high as 30% (Thomas, 1992).

Nitrogen management is very critical in success of cereal-clover forage mixture as N subsidy to cereal by N fixation of clover fix the adverse effect of some soil nutrient deficiency contributing towards higher production (Matusinsky and Hrabe, 2003). However, mixtures fertilized with N would tend to favour the growth of cereal component and hence more DM yield is expected (Anil et al., 1998). Therefore, if objective is to have a handful of clover % in Cut-1 then N application should be low. Environment also plays a key role in the productivity of binary mixtures. Season with more rainfall and soils with more minerals is likely to yield higher herbage DM yields (Vasilakoglou and Dhima, 2008; Campillo et al., 2005).

**Forage quality**

Cereals are nutritionally inferior forage stuff owing to its lower protein and higher fibrous contents. Furthermore, decline in CP concentrations with maturity in cereal
is more rapid than clovers (Khorasani et al., 1997; Ross et al., 2005a). However, animal feed consisting of only clovers can cause bone abnormalities in animals due to incorrect ratio of Ca and P and cereal in mixture helps in correcting the Ca and P ratio and lower the bloating incidence in animals (Hall et al., 1991). Inclusion of clover in cereal forage production system will not only lower the cost of production by replacing N fertilizers but also improve the quality of forage resulting in increased intake and digestibility of the forage (Ross et al., 2005a; Butler et al., 2012). Cereals have higher concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF), compared to legumes (Moore and Jung, 2001); therefore, clovers can lower the fiber contents of the mixture. For instance, Sleugh et al. (2000) and Ross et al. (2005a) observed 30% and 30 g kg⁻¹ DM decrease in NDF concentration in wheat-kura clover and oat-berseem mixtures, compared to sole cereal component, respectively, that is indicative of increased intake. A SGC-clover mixture also minimize the N losses owing to cereal uptake of mineral N from soil and slower rate of N mineralization on decomposition (Azo et al., 2012). Though sole clover could have higher CP concentrations, but CP yield ha⁻¹ would generally be higher in cereal-clover mixtures (Shoaib et al., 2013) as CP ha⁻¹ largely depends on DM production (Eskandari et al., 2009). Better quality forage from SGC-C mixture is mainly due to two reasons: firstly, due to the transfer of fixed nitrogen by clover to the cereal companion in mixture during growth, and secondly, due to the legume presence in harvested forage. Therefore, to witness the improvement in forage quality through clover inclusion, some handful proportion of clover in the mixture has to be assured. Nutritive value of clover regrowth is not much affected by presence of cereal prior to Cut-1 however, cereal regrowth can lower the forage quality of regrowth cut (Andrzejewska et al., 2014).

In mixtures, cereals are more efficient in absorbing soil N, compared to clovers, due to their differential abilities in depleting soil N resources (Munoz and Weaver, 1999) hence clovers have to depend on symbiotic nitrogen fixation for their N needs in mixture (Giambalvo et al., 2011; Vinther, 2006). Co-existence of legume and cereal roots in soil increase the likelihood of N transfer from legume to cereal through soil solution (Paynel and Cliquet, 2003; Giambalvo, 2011). Chances of N transfer from legume to companion crop are more when their roots interact within the proximity of 0.5 mm of root exudates (Zhang et al., 2004). Furthermore, SGC compared to dicotyledonous have greater chances of receiving N from legumes owing to their fibrous root system (Pirhofer-Walzl et al., 2012). In their study, Dahlin and Stenberg (2010) assessed that nitrogen transfer from clovers to grass made up 30-57% of grass nitrogen.
Legume species differ in their ability to transfer fixed N to companion grass (Louarn et al., 2015). Pirhofer-Walzl et al. (2012) reported that white clover, red clover and alfalfa (closely related genera to *Trifolium*) approximately transferred 9 kg N ha⁻¹ to *Festulolium* and ryegrass roots. However, in their study, Ledgard (1991) found that amount of N transferred from white clover to ryegrass was 54 to 102 kg N ha⁻¹. In some other studies, amount of N transferred was 36 kg from red clover to perennial ryegrass (Dahlin and Stenberg, 2010), while from white clover to ryegrass was 49.5 kg ha⁻¹. Contrarily, certain scientist found no apparent fixed N transfer from clover to ryegrass (McNeill and Wood, 1990; Giambalvo, 2011). Among the clovers, white clovers is more efficient N donor species, compared to other clovers and match well with grasses in terms of sustainable N supply (Pirhofer-Walzl et al., 2012: Høgh-Jensen and Schjoerring, 2001), that could be attributed to higher proportion of fine roots with lower C:N ratio resulting in more rapid release of N (Louarn et al., 2015).

Among other nutrients, berseem clover increased Mn influx to oat and ryegrass by a factor of four in mixture (Arneja and Sadana 2012). In multi-layer rooting system found in mixed cropping systems, subsoil K sources are effectively utilized (Ehrmann and Ritz, 2014). In ryegrass-clover mixture system, subsoil K uptake was up to 55% (Witter and Johansson, 2001). In conclusion, quality of mixed forage is improved by in-season N transfer from clover to cereal, presence of clover in harvested stuff, influx of other nutrients to cereals and greater exploitation of subsoil minerals.

**Competition and clover suppression**

When two crops are sown in same field, competition among them may occur (Vandermeer, 1989), that may affect survival, growth and reproduction of at least one of the species in mixture (Crawley, 1997). However, competitive relationship among mixture components can be manipulated to maximize the productivity of mixture (Giambalvo et al. 2011). Objectives of research into SGC-clover mixtures is to explore intraspecific relations and their harmonization as a factor of agreement between forage production and quality (Matusinsky and Hrabe, 2003). Zhang and Li (2003) proposed a competition-recovery production principle for long duration-short duration intercrops co-existing intercropping system, according to which, interspecific competition favors growth, nutrient uptake and yield increase of dominant species but inversely effects the subordinate species. However, after the harvest of dominant species the sub ordinate species recovers so that final yield is maintained or enhanced.

In SGC-clover mixtures, many factors favors cereal growth during the time of their co-existence. Some of the factors that contribute to competitive advantage to cereals are
plant height (Korres and Froud-Williams, 2002), early plant/canopy establishment, and high growth rate (Ross *et al.*, 2005a). In addition, cereals are more productive than clovers in relation to unit amount of N accumulated owing to photosynthates being respired by legumes for N fixing (Osaki, 1994). Plant height is an important factor in competitiveness of crop (Lemerle *et al.*, 2001; Mason *et al.*, 2007; Zerner *et al.*, 2008). Taller plants, generally, have most of their leaves higher in canopy that help in more light interception and suppression of small plants due to shading. According to Ross *et al.* (2004a), PAR available to berseem in barley-berseem and oat-berseem mixture was 33% and 47%, respectively.

Early plant vigor is highly associated to its competitive ability (Lemerle *et al.*, 2001). Early plant establishment and reduced time to maturity improves the crop response to competitor in vicinity (Mason *et al.*, 2007). While evaluating oat-berseem mixture for forage under varying oat densities, Ross *et al.* (2005a) observed maximum LAI ranging from 7.3-7.6 at 65-66 days after planting, when they used 240 seeds m\(^{-2}\), while range was 5.6-5.7 at 60 seeds m\(^{-2}\). This early canopy development of cereals than berseem caused considerable shading to the berseem plants, that are at lower layer of canopy (Ross *et al.*, 2005a).

Root exudates of oat and Italian ryegrass have been reported to contain various toxic substances, that can effect seedling growth of companion clover (Iannucci, 2006). Clover suppression by cereals is also traced in allelopathic effect of exudates from live roots of forage cereals on root length and early seedling development of clover (Iannucci, 2006). However, more research work is warranted to find out effectiveness of this phenomena for various SGC-clover mixtures under field conditions.

Research into the small grain cereal-clover mixture suggested that yield optimization could be achieved by the mixtures, but same time cereal imposes a severe competition on clover component, that is reflected by poor proportion of clover in produce and less clover persistence. Relatively early emergence of clover, reduction of competition from cereal, early timing of Cut-1, adequate soil moisture, and a lengthy period of regrowth can promote the clover proportion in cereal-clover mixture (Ross *et al.*, 2005b).

**Effect of relative proportion**

Relative proportion of intercrops is an important factor affecting competitive ability of crops and forage production in mixture (Vinther, 2006). Optimum plant densities of small grain cereals and clovers monocultures determined for different regions are of little or no value in predicting their relative densities in their binary mixtures (Bulson *et al.*, 1997). Changes in the sowing rate of dominant species, i.e. cereals, have greater effect on species composition and Cut-1 herbage DM yields.
(Ross et al., 2003; Ross et al., 2005b; Vasilakoglou and Dhima, 2008). Increased seeding rates of cereal favors early season ground cover and DM accumulation however final DM yield is unaffected of the seeding rates (Brennan et al., 2009). Productivity of mixtures are enhanced when cereal densities are kept low mainly due to less competition to clover prior to Cut-1 that will translate into higher clover regrowth subsequently (Ross et al., 2005b: Shoaib et al., 2013). Less plant densities of cereals in mixtures make available more soil N to cereals, compared to monoculture and this complementarity effect can partly explain cereal dominance in mixture (Schipanski and Drinkwater, 2012; Louarn et al., 2015). On the other hand, less clover density will lead to lower amount of atmospheric derivated N (Neumann et al., 2007). However, in presence of competitively superior companion, impact of higher clover seeding rate would be little early in the season (Ross et al., 2004a).

**Cutting management**

Some important growth stages of small grain cereals are defined below (adapted from Collar and Aksland, 2001).

- **Boot:** Just prior to heading (appearance of grain head or spike), with the flag leaf (top most leaf) fully expanded. The grain head is not yet visible, but can be felt near the top of the plant inside the sheath of the flag leaf.

- **Heading:** Grain head (spike) emerges from the sheath of the flag leaf.

- **Flower:** Grain head and supporting stem have fully emerged from the sheath of the flag leaf; anthers have emerged from the grain head and are shedding pollen.

- **Milk:** Grain kernels are developing and are filled with a white, milky liquid.

- **Soft dough:** Grain kernels are well formed and have the consistency of a rubbery dough.

Cutting management in forage mixture could be used to manipulate the pattern of seasonal yield and aids in temporal complementarity (Ross et al., 2005b). Herbage DM contents in cereals increase with advanced maturity (Khorasni et al., 1997). Decrease in feeding value of forages with advanced maturity is due to physio-chemical changes in plants (Vranic et al., 2009). In plants, CP contents decrease while ratio of cell wall contents increase with maturity that reduce the forage intake and digestibility of forages (Jancik et al., 2008; Azo et al., 2012), which has a practical significance. Cutting the forage too late limits the animal growth by low N contents (Kaiser et al., 2007), while forages cut at early stages have poor N capture efficiency in the rumen (Aibibula et al. 2007). However, Andrzejewska et al. (2014) is of the view that cutting time of the cereal-clover mixture would not affect the second or third cut clover regrowth yield. Contrarily, time of the Cut-1 will influence the regrowth of
cereal. In oat/rye/triticale-clover mixtures, cereals deprived of regrowth, when harvested at early heading stage (Shoaib et al., 2013; Andrzejewska et al., 2014), which may be attributed to decrease in number of tillers capable of regrowth with delayed cutting (Ross et al., 2005b).

According to Khorasani et al. (1997), DM concentration is almost similar in all small grain cereals up to booting stage. Similarly, almost all the small grain cereals have the same pattern of DM accumulation and maturation, nevertheless varieties may differ in onset of different growth stages (Fohner, 2002). In SGC-clover mixtures, cutting largely depends on the growth stage of the associated cereal because of the higher contribution from cereal in DM production (Shoaib et al., 2013).

**Regrowth of clovers**

Seeding rate of cereal in sowing mixture has a key effect on clover regrowth yields (Ross et al. 2005b; Contreras-Govea and Albrecht, 2005). Contreras-Govea and Albrecht (2005) observed on average 0.8 Mg ha⁻¹ yield reduction at first regrowth from SGC-kura clover, compared to kura clover monoculture. According to Ross et al. (2005b) lower berseem regrowth yield in oat-berseem mixture, compared to berseem monoculture was due to lesser residual leaf area after Cut-1 as regrowth of annual clovers depends upon residual leaf area and rapid leaf generation rather than stored food (Kendall and Stringer, 1985).

Furthermore, lack of space for berseem to establish at early growth stage reduced its regrowth ability (Ross et al., 2005b). Nonetheless, clovers have excellent ability to recover from stress imposed by cereal prior to Cut-1 and produce almost similar total seasonal yield to clover monoculture in their regrowth phase (Shoaib et al., 2013; Andrzejewska, 2014). According to Giambalvo et al. (2011), berseem has greater capacity to recover after defoliation, compared to other clovers and frequent cuttings of berseem make it more competitive. This is why, cereal dominates mixtures prior to Cut-1, while clover dominates during regrowth phases (Ross et al., 2005b).

**Spatial arrangements**

Temporal complementarity is more likely to have higher yield advantage in intercropping system than spatial complementarity (Willey, 1979). However, spatial complementarity for SGC-clover is equally important as some minimum space is required for clover to establish (Ross et al., 2005b). Without an initial space for clover, its regrowth yield reduced in spite of temporal facilitation (Ross et al., 2005b).

Intercrops in mixtures arranged to achieve planting uniformity are more probable to increase productivity (Olsen et al., 2005), that could be better achieved in row planting. One way to achieve planting uniformity is to plant intercrops in grid pattern, but this method involves
extensive tractor use that will increase soil compaction and expenses on fuel, labor and machinery maintenance (Brennen et al., 2009). In their study, Giambalvo et al. (2011) achieved higher DM yields in berseem-ryegrass mixture from alternative rows, compared to same row (mixed seed sowing). Wider row spaces of cereals in mixture would benefit clover component and will assure handful proportion in mixture (Annicchiarico and Tomasoni, 2010). Planting arrangement is also a key factor in N transfer from clover component to cereal component. Chances of effective N transfer increase when root systems of both component are in proximity (Giambalvo et al., 2011). However, reducing the intimacy of the components of cereal-legume mixture will benefit less competitive component of the mixture (Annicchiarico and Tomasoni, 2010; Giambalvo et al., 2011). Therefore, decision regarding planting arrangement could be done on base of type of species in mixtures and to achieve uniformity among intercrops.

**CONCLUSIONS**

Complexity in the growth, interactions and the conditions in which mixtures sown is not suitable to draw general conclusions, but some comments can be made about the said mixture. Early maturing and short stature cereals or their cultivars are more suitable to mix with clovers. Efforts should be made to maximize the clover contents in Cut-1 DM yield as high as 30%, which may be achieved by selecting a more competitive clover species or identification of less competitive cereal component. Presence of clovers and below ground nutrient facilitation enhance the forage nutritive value of mixture. To assure good Cut-1 DM yield and vigorous clover regrowth, cereal seed proportion should be kept low to minimize competition. Cutting time of the mixture should not be later than heading stage of cereals as at this stage DM yield and forage quality is in compromise, while delaying the cutting will deteriorate the quality of mixture and decrease clover regrowth potential. Maintaining uniformity between intercrops is more likely to achieve greater productivity. Decreasing the proximity between cereals and clover (wider row spaces) would yield higher DM yields, but lower N uptake by cereal. Certain management factors of SGC-clover mixtures are not discussed in this review to keep it in reasonable size. However, a future review should also discuss fertilizer, weed and irrigation management of various SGC-clover mixtures. Moreover, role of allelochemicals in mutual interaction of SGC-clover is yet to explore.

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