# CHAPTER II
# LITERATURE REVIEW

## 2.1 Integrated farming systems in rainfed uplands

### 2.1.1 The existence of farming systems

Integrated farming system is conceived as a practice of growing fruit trees and windbreak species in association with cover crop on the same piece of land. The Chom Tong Land Reform Area, where the study is intended to represent the rainfed upland area. The farmers prefer to integrate the fruit tree with field crops such as soybean, which rehabilitate the income and natural condition. (Radanachaless *et al.*, 1993). The fruit trees grown in this area include mango, tamarind, longan, jackfruit and custard apple. The farmers are mostly inclined to grow mango that is integrated with cash crop such as soybean (Radanachaless and Timm, 1991), upland rice, chili, corn and legume species in the rainy season. Moreover, in the rainy season, the natural vegetations are also the source of forage to domesticate animals (Radanachaless and Gypmantasiri, 1991).

Some farmers currently want to change cropping systems at the expense of existing field crops such as soybean or other cash crops in the fruit orchards as the yield declined because the area has many aforementioned problems. Moreover, there are also the new alternative ways to just grow the fruit tree, especially the mango orchard with the perennial cover crops to augment the surface soil properties, suppress weeds, conserve moisture and feed cattle (Radanachaless *et al.*, 1999).

### 2.1.2 Geographic and climatic characteristics of Doi Lor district

The Chom Tong Land Reform Area at Yang Kram subdistrict, Doi Lor district, Chiang Mai is the rainfed upland area in the Upper North of Thailand. The site was characterized by sandy loam (Korat soil series) with average annual rainfall

of 900 mm., altitude 300-360 m. above mean sea level, slope 3-10%, average temperature 27-47° C, especially in April-June (Radanachaless *et al.*, 1993).

### 2.1.3 Physical and biological constraints of rainfed upland

#### 2.1.3.1 Soil fertility

The Chom Tong Land Reform Area represents a fragile agroecosystem with severe degradation of natural resource, soil erosion, shallow soil surface, low organic matter, sand silt soil, unretained water, low water level, dry area, and high soil temperature (Radanachaless and Gypmantasiri, 1991). As the problems of soil degradation, soil erosion, and yield decline in the area are recognized by local farmers, the function of improving soil fertility and sustaining crop yields of legume species could provide significant contribution to sustainable land use in the marginal uplands (Gypmantasiri and Kittiwat, 1993).

#### 2.1.3.2 Weed interference

The problems are found in farmers' management practices in farming system, especially in weed management, which is caused weed problems that compete in mango plantation. Soybean and other crops can decrease the partial problems of weed in the end of rainy season, but some farmers only grow the fruit trees without any intercultivation. Consequently, the weeds can establish in the fruit tree orchard (Radanachaless and Krasaechai, 1994).

#### 2.1.3.3 Fire

The initial establishment of mango cv. Kaew has had serious problems with weeds interference due to grass and broadleaved weeds residue have become source of fire during the dry season. Fire is a potential hazard that cause severe damages on both young and mature fruit trees almost every year. (Radanachaless and

Krasaechai, 1994). Because some of farmers' practice slash-and-burn for weeding purposes with little precaution, fire becomes a common threat there.

#### 2.1.3.4 Animal feed

When decade ago, the rainfed upland area had enough natural feed for cattle and then the farmers extended the frontier to grow fruit trees and crops. Consequently, the natural feed area declined, and the grazing cattle destroyed the young fruit trees and crops (Radanachaless, 1990). In addition the rainfed upland area being dry and infertile, could not support proportionate number of livestock as the cultivated area expanded (Radanachaless and Gypmantasiri, 1991).

#### 2.1.3.5 Pests and diseases

The productivity declined with low quality and quantity of output. Natural enemies in the system died out resulting in the frequent outbreak of pest and disease (Radanachaless and Gypmantasiri, 1991).

#### 2.1.3.6 Water constraint

About 90% of area uses the rainfall, although this area has 8 reservoirs that were dug by the Chiang Mai Provincial Land Reform Office (PLRO), but it incurs high cost to take it to domesticate animals. In addition steep and deep reservoir is also not appropriate for the cattle (Radanachaless, 1990). The integrated agriculture on rainfed upland area especially, the agroforestry systems must use the major water. Variable quantity and uneven distribution of the rain are limiting the opportunity of growing the crops and fruit trees (Radanachaless and Gypmantasiri, 1991). When the upland areas are changed to agricultural area, the water resource is the main obstacle which depends on the rain, limited available soil moisture during dry season and soil related problems restrict opportunities for crop intensification. In addition,

inappropriate farmer management practices caused the first year mango tree failed to adapt to rainfed upland environment (Radanachaless and Krasaechai, 1994).

**2.2 Conceptual framework**

Growing cover crops in association with grain crops, horticultural crops, and plantations, in appropriate sequence or combination and with judicious management, can help achieve objectives of sustainable agriculture (Lal *et al.*, 1991). The role of cover crops in augmenting soil properties and thereby conferring sustainability to the system is schematically presented in Figure 2.1. Cover crop that remains alive for part or all of the cropping season is called smother crop. It may be either perennial or annual. Species that are perennials or self-seeding annuals have the advantage of eliminating the need for annual seeding and associate seedbed preparation (Teasdale, 1998).

Legume cover crop, *Stylosanthes hamata* is a component of integrated farming systems in rainfed uplands. It plays potential contribution not only on increasing the yield but also improving the quality of mango. The cover crop benefits in two ways i.e. direct and indirect. The direct benefit includes ground coverage and used as fodder for livestock. As ground cover, it reduces fire hazards during dry season and inhibits noxious weeds. As fodder, it becomes favorites for livestock. From the livestock, farmers can get meat, which eventually increases income. On the other hand, indirect benefit includes increasing soil fertility by biological nitrogen fixation. In addition, it reduces soil erosion. Moreover, as livestock likes it very much, it increases the number of livestock which eventually produces more farm yard manure. Thus, *S. hamata* appears to be an extremely promising component in the mango based integrated farming (Radanachaless *et al.*, 1999).

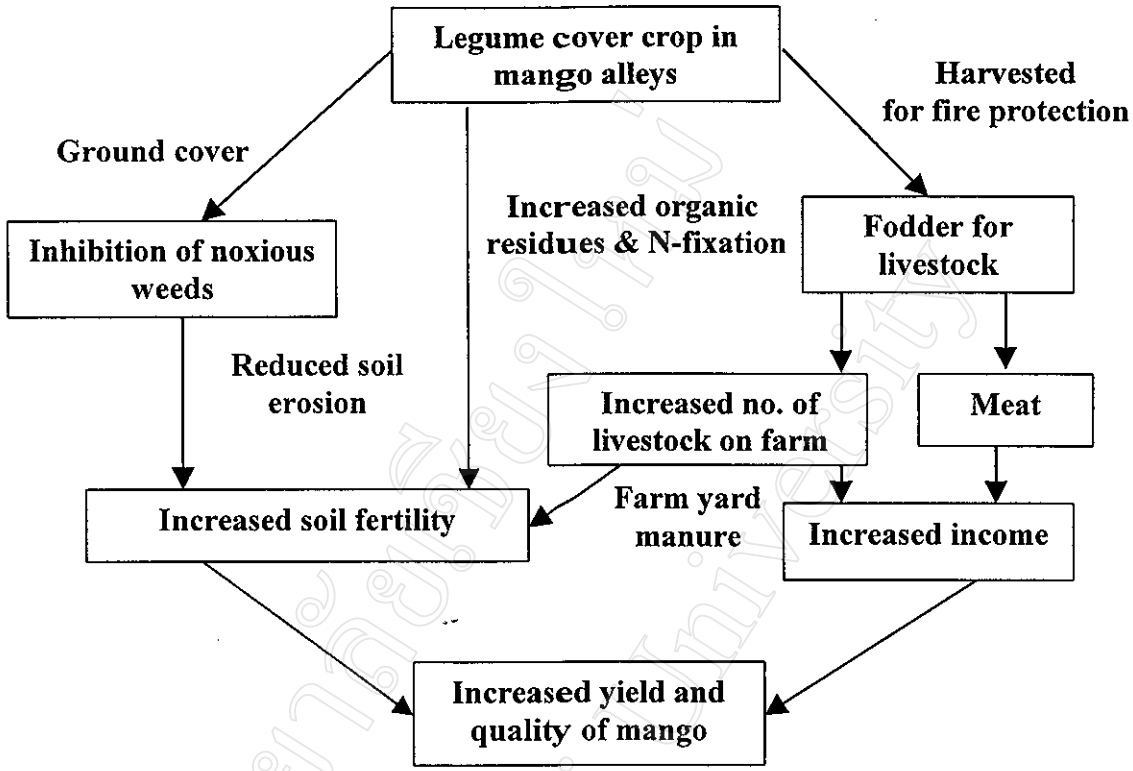


Figure 2.1 The potential contribution of legume cover crop (*Stylosanthes hamata*) in mango-based integrated farming systems in rainfed uplands (Radanachaless *et al.*, 1999)

However, researches on the appropriate cutting frequencies of the *S. hamata* and concomitant weed management measures under this upland rainfed condition in the Upper North are virtually lacking so far. The study was aimed at abridging the knowledge gap so as to reconcile the land management practices in integrated upland farming system through the use of the legume cover crop, *S. hamata.*

## 2.3 *Stylosanthes hamata*

### 2.3.1 Description

Caribbean stylo (*Stylosanthes hamata* cv. Verano) is classified to family Leguminosae and subfamily Papilionoideae (Humphreys, 1995). The name "Verano" suggests in Spanish "dry season", native to West Indies and the lands, which border

the Caribbean Sea. The Thais call "Verano stylo" or "Caribbean stylo" or "Hamata legume". Verano stylo is a species with several varieties. This cultivar released in Australia represents only one form of *S. hamata*, which to the naked eye is identical in appearance (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm). It was introduced from Australia into Thailand in 1970 as a research project based on Khonkaen University (Department of Livestock Development, 1995).

Verano stylo is an annual or a short lived perennial herbaceous legume (Humphreys, 1980; Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm). It produces a lot of seed at almost any time of the year even under grazing, if allowed to seed without grazing, it tends to behave as an annual, but 30-40% of plants will perennate under grazing, and continue to grow into the dry season after flowering. In addition, in the no tillage (NT) it behaves either as a self-regenerating annual or a biennial plant, with generally 40 percent of plants surviving from one wet season to a second (Queensland Beef Industry Institute, 2000: http://www2.dpi.qld.gov.au/pastures/verano.html; Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm). Verano stylo has a many branched, semi-erect growth habit, 40% are erect and 25% prostrate and grows to 75 cm high (Tarawali *et al.*, 1994; Northern Territory of Australia, 1999: http://www. tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm). The stems have short white hairs down one side. Leaves are trifoliate, with the leaflets being lanceolate in shape, generally 19-37 mm long and 3-6 mm wide (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

The inflorescence consists of a compact head containing 8 to 14 small yellow flowers. Flowering commences in February and continues until soil moisture is exhausted. Pods consist of two single seeded segments which readily separate. The

upper segment, including a slightly curled beak (hook) is 6-8 mm long. The lower segment is not hooked. (Humphreys, 1980; Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm). Seeds are small, 2-5 mm long, kidney shaped and medium to dark brown in color. There are 270,000 seeds with pods per kilogram and 450,000 seeds without pods per kilogram (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes /562.htm). It has the rapid seedling growth ability and well-grown seed crops can yield up to 1 ton/ha (Humphreys, 1980).

Caribbean stylo is similar in appearance to Townsville stylo (*S. humilis*). The most obvious differences are that Townsville stylo has long bristles (hairs) on its stem and Townsville stylo pods are longer (9-11 mm) with a longer beak (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/ 562.htm).

**2.3.2 Climatic and edaphic adaptation**

Caribbean stylo is a native of the Caribbean Islands and Tropical Central and South America. It grows well in the hot tropics and warmer subtropics (Humphreys, 1980). Thus Caribbean stylo is also clearly well adapted to the hottest districts in northeast Thailand (Wilaipon and Pongskul, 1984). It is also grown in climate with a pronounced wet season followed by a dry season, which has been successful in regions of 600-1,700 mm rainfall over a growing season of 15-25 weeks (Echo, 2000: http://www.echonet.org/seeds/Seed_catalog-overseas2000.htm). In addition, it is adapted to a wide range of infertile, sandy-surfaced and well-drained soils (Humphreys, 1980; Queensland Beef Industry Institute, 2000: http://www2.dpi.qld. gov.au/pastures/verano.html; Northern Territory of Australia, 1999: http://www. tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm), with the exception of the heavier clay soils. It is very tolerant to high acidity. Verano stylo has grown well on waterlogged,

but not flooded soils (Northern Territory of Australia, 1999: http://www.tucows. nt.gov.au/dpif/pubcat/agnotes/562.htm). Verano stylo as the legume-*rhizobium* nitrogen fixing association is less impaired by high exchangeable aluminium in the soil than it is in almost all other cultivated pasture legumes (Humphreys, 1980).

Verano stylo is not shade-tolerant but it is drought tolerant and can survive long dry seasons, if not grazed it tends to drop its leaves towards the end of the wet season, that is from April on to June when only bare green stems is left standing. Verano stylo plants will generally not survive a fire unless there is still moisture in the ground following the wet season, but a pasture usually regenerates well from seedlings in the wet season following burning (Northern Territory of Australia, 1999: http://www.tucows. nt.gov.au/dpif/pubcat/agnotes/562.htm).

### 2.3.3 Management

#### 2.3.3.1 Fertilizer requirements

Verano stylo can grow and persist on infertile soils, but in the top end it responds well to applied phosphorus and sulfur, producing high yields. Generally, superphosphate ($P_2O_5$) or its equivalent at 50-150 kg/ha should be sown with the seed. Maintenance dressings of 25-100 kg/ha superphosphate should be applied annually. Moreover increases in nutrient content and productivity normally occur in response to phosphatic fertilizer application (Little and Agyemang, 1994; Nilnond and Chatupote, 1996). While a high response of Verano stylo to P was confirmed in Shika at the National Animal Production Research Institute (NAPRI). At 0 and 30 kg $P_2O_5$ per hectare, yield increased from 2.8 t to 6.0 t DM/ha. This increased further to 8.7 t DM/ha at 120 kg/ha of $P_2O_5$; thus a level of 30 kg $P_2O_5$ per hectare was close to the economic optimum for yield (de Leeuw and Mohamed-Saleem, 1994). In addition Nilnond and Chatupote (1996) reported that P deficiency might be limiting factor on Verano stylo growth. Appropriate rate of P application might be 50-100 kg/ha.

Applications of potassium, molybdenum or zinc may be necessary on some soils (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

**2.3.3.2 Establishment**

Verano stylo has been successfully established in drier areas by oversowing into a burnt area of native pasture. In the wetter areas of the top end, establishment has been more successful when sown into a well prepared seedbed or into an area which has been disturbed by at least one rough cultivation. Seed can be sown at 2-4 kg/ha before the wet season (Northern Territory of Australia, 1999: http://www.tucows.nt. gov.au/dpif/pubcat/agnotes/562.htm). All pastures seed stocks of *S. hamata* at the National Animal Production Research Institute (NAPRI) research station near Zaria in Nigeria were high giving initial seedling densities of 300-1,000 plants/$m^2$ and producing final yields (dry matter) of 4-8 t/ha. Due to this good initial establishment, competition from volunteer vegetations was low and final yields contained 60-80% of legume while Survey (2000) found that 89.82% and 10.18% of Verano stylo and weeds respectively. These results confirm that *S. hamata* can retain long-term productivity. It provided a large seed pool, which is kept intact across growing season (de Leeuw *et al.*, 1994). McIvor and Gardener (1998) found that maximum seed numbers (i.e. for an individual plot in 1 year) were 3,150 seeds/$m^2$ and 10,560 seeds/$m^2$ at Hillgrove and Cardigan of Northeastern Queensland respectively. The soil seed reserves give natural seedling regeneration in the succeeding wet season, which replaces the died plants. Seed can be produced almost any time of the year (Wilaipon and Pongskul, 1984).

It generally behaves as a weak biennial, regenerating well from reserves of seed in the soil in the next wet season, and can thus survive fires which kill the parent plant (Queensland Beef Industry Institute, 2000: http://www2.dpi.

qld.gov.au/ pastures/verano.html). Verano stylo can be inoculated with a special *S. hamata* inoculant to ensure nodulation. This has not been necessary to date in the no tillage as Verano stylo has not been inoculated and has nodulated effectively with native soil rhizobia (Northern Territory of Australia, 1999: http://www.tucows. nt.gov.au/dpif/pubcat/agnotes/ 562.htm).

**2.3.3.3 Grazing**

Verano stylo is well accepted by stock where it has a history of phosphorus fertilization. Where it has not been fertilized stock will often avoid it. Generally, in the year of establishment, Verano stylo should not be grazed before it has set seed as the first year stand is generally not high yielding such as 2-3,000 kg/ha dry matter, and seed needs to be set to allow it to thicken up. Heavy grazing following burning and oversowing for establishment is recommended to reduce competition particularly from established perennial grasses. This works particularly well with stock which are not familiar with *S. hamata* as they will not graze it when it is young and green, while stock which know it will do so. Verano stylo is more likely to behave as an annual plant if it is not grazed. Even after a stand has dropped most of its leaf it is well grazed by stock, including horses, which graze the standing green stems and lick up the fallen leaf and seedheads from the ground, provided it has not become mouldy following dew or rain (Northern Territory of Australia, 1999: http://www. tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

**2.3.3.4 Yield**

Good quality hay can be made from Verano stylo if it is cut early while it is green and leafy. Later cuts will be of lower quality because at least some of the leaf will have been dropped. Dry matter yields up to 10,000 kg/ha and seed yields up to 900 kg/ha have been recorded in the no tillage. Where the dry matter yields are high, i.e. 7,000-10,000 kg/ha of dry matter, due to high fertilizer inputs, the quality of

the standing material is reduced as the pasture lodges during wet weather and the lower leaves rot, leaving a higher proportion of stem material (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

Verano stylo is a fast growing forage legume with dry-matter producing up to 548 kg/ha at 90 DAS under the upland condition in the north of Thailand (Amaruekachoke *et al.*, 1994). Dry-matter of *S. hamata* production with cutting interval of 30, 45, 60 and 75 days were 186.6, 293.4, 228.0 and 279.0 kg/ha respectively in the second year (Department of Livestock Development, 1995). While dry matter yields of hamata during the wet season in the second year at Khon Kaen was 1,899 kg/ha (Walaipon *et al.*, 1989). Department of Livestock Development (1995) found that from the 30-75 days cutting interval in the first and second year the dry matter production was 203.8-257.9 and 186.6-294.1 kg/ha respectively. But Chansiri *et al.* (1988) cited in Department of Livestock Development (1995) found that 45-60 days cutting interval in the first and second year gives 226.9-229.3 and 270.9-282.6 kg dry matter per hectare respectively.

**2.3.3.5 Ground cover**

Verano stylo grows on a very wide range of soils, and is especially suited to well-drained sandy soils of low fertility. It is very tolerant to high acidity, and the legume-*rhizobium* nitrogen fixing association is less impaired by high exchangeable aluminium in the soil than it is in almost all other cultivated pasture legumes (Humphreys, 1980). Amaruekachoke *et al.* (1994) intended to use forage legume for rehabilitation of degraded land in Northern Thailand. They found that *S. hamata* established complete ground cover at 150 DAS in January and thereafter maintaining over 60 percent of ground cover until July.

**2.3.3.6 Improving soil fertility**

Soil fertility is inseparably associated with crop productivity. For the sustained productivity, maintenance of soil fertility is extremely paramount. Management of crop residues, supplemental use for manures and fertilizers, use of legumes in the rotations and conservation tillage are the components of soil fertility management. Leguminous species are often grown specifically for nitrogen fixation, which is carried out by free-living soil bacteria and by living symbiotically with plants (Kiff *et al.*, 1996). Kram *et al.* (1998) reported that rhizobial nodulations of *S. hamata* grown in sandy loam soil at Ubonratchathani Field Crops Research Center in early and late rainy seasons. There was low tendency of nodulations in no-external-input condition, and nodulation increased with the addition of some level of external inputs.

Udchachon *et al.* (1996) found that yield of cassava was not significantly different between the plots with *S. hamata* grown for two and three years continuously. While the yield of cassava in rotation was significantly higher ($P<0.01$) when compared with only cassava grown for three years continuously. Similarly, Simaraks *et al.* (1989) cited in Udchachon *et al.* (1996) found that yield of cassava was 739.84 and 370.88 kg/ha in the plot where *S. hamata* was grown for three years and the plot grown only cassava for three years respectively.

**2.3.3.7 Weeds suppression**

When used for weed control, the function of a cover crop may be either to prevent or reduce weed establishment by competing with the weed species, or to eliminate or control weeds, which have already become established. In many cases, it is important to prevent weeds from seeding and building up a large weed seed bank. In slash and burn agriculture, the role of the cover crops is to prevent the weed flora changing from a composition dominated by broadleaved weeds to one dominated by

more aggressive, grassy weeds. Grass-like weeds are difficult to eliminate except through long fallow followed by burning (Kiff *et al.*, 1996). In addition to reduce herbicide, technology for weed control in conservation tillage incorporates short-term crop rotation (Lal *et al.*, 1991).

Verano stylo has a vigorous growth habit, which enable to compete with weeds. It is mentioned that the biomass legume to weed ratio of 1:0.15 this species could be used as forage as well as cover crop in the fruit orchard (Amaruekachoke *et al.*, 1994). In addition, heavy grazing following burning and oversowing for establishment is recommended to reduce competition particularly from established perennial grasses (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

Although, there is a great promise in using cover crops such Verano stylo to aid in weed control, much research is needed to gain full advantage of the system. Some problems that need attention are the lack of suppression of perennial weeds, and annual and perennial grasses (Worsham, 1991). An often-overlooked tool in reducing weed competition is to establish a good crop stand, in which plants emerge rapidly and shade the ground. The plant that emerges first and grows the most rapidly is the plant that will have the competitive advantage. Establishment of adequate plant populations is very helpful in reducing weed competition. Everything possible should be done to insure cover crops, not weeds, have the competitive advantage (Cooperative Extension Services, 2000: http://edis.ifas.ufl.edu/BODY_CV113). Less aggressive cover crops may not be able to compete with weeds, it may be dependent on cutting frequency and weed management.

Although the long-term sustainability of Verano pastures is dependent on many factors (de Leeuw and Mohamed-Saleem, 1994), dry season cutting

management and weed control are essential. Cutting frequency is one of the practices, which influences the pattern of interference between the species affecting on competition for light, vegetative spread, and partitioning of biomass to parts of the plants above and near or below ground (Sullivan, 2000: http://www.attra.org/attra-pub/weed.html). In addition, weeds also affect forage quality as much as or more than crop maturity. Drought is one of the major environmental factors affecting forage quality and vegetative growth. Udomprasert and Sawasdiphanich (1995) found that under water stress condition, protein content increase in Verano Stylo. But it has no effect on acid-detergent fiber content. de Leeuw and Mohamed-Saleem (1994) found that response to defoliation during the growing season was marked indication that by cutting hamata every 6-9 weeks 5.1-5.8 t/ha was produced in the first year increasing to 6.8-7.2 t/ha in the second year, or 105-115% and 60-70% above the end-of-season yields respectively, from single harvest. The intrusion of summer weeds into alfalfa (*Medicago sativa* L.) hay fields, Kallenbach and Cudney (1997) found that 35 days harvest interval maximizes hay quality by reducing weed competition while considering forage maturity. However, Verano stylo can be sown in mixtures with all of the grasses recommended for use in the top end of the no tillage except for the floodplain grasses (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).

**2.3.3.8 Pests and diseases**

Verano stylo is fairly resistant to the fungal disease anthracnose (*Colletotrichum gleosporioides*) (Tarawali *et al.*, 1994; Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm; Queensland Beef Industry Institute, 2000: http://www2.dpi.qld.gov.au/pastures/verano.html). In the field it shows some anthracnose lesions on stems and leaves but it causes no plant death. In addition, the fallen leaf is susceptible to moulding after dew

and out of season showers (Northern Territory of Australia, 1999: http://www.tucows.nt.gov.au/dpif/pubcat/agnotes/562.htm).