EFFECT OF INTERCROPPING PEA WITH CANOLA OR YELLOW MUSTARD

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ABSTRACT

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Effect of intercropping pea with canola or yellow mustard.

Major professor: Dr. E. H. Stobbe, Department of Plant Science

Intercropping is a farming practice that has recently received attention as a means of improving land productivity in western Canada. The main reason for such advantage would appear to be that when grown together the component crops complement each other and make better use of environmental resources. The objectives of this study were to determine the effect of intercropping pea with yellow mustard or canola on growth and development, and yield of each of the component crops.

The crops were planted in both sole and mixed stands. The sole stands of pea were sown at 120 and 180 kg/ha Canola sole stands were sown at 2 and 6 kg/ha whereas those of yellow mustard were 3 and 9 kg/ha. Mixtures were sown at 120 kg/ha of pea with either 2 kg/ha of canola or 3 kg/ha of yellow mustard. 'Century' pea was used in 1990 and 'Bohatyr' pea was used in 1991. 'Westar' canola was used in 1990 and 'Legend' canola was used in 1991. 'Gisilba' yellow mustard was used in both years. In 1990, dry matter accumulation of pea was not affected in the intercrop, while that of both yellow mustard and canola was reduced (significant at $p<0.05$). In 1991, however, dry matter accumulation of pea was reduced in the intercrop, along with that of yellow mustard and canola (all significant at $P<0.05$). Pea dry matter was reduced more by yellow mustard than by canola. Yield of pea was reduced by 0.5% and 22% when intercropped with canola and yellow mustard, respectively, in 1990. Yields of pea was reduced by 41% when intercropped with canola, and by 38% when intercropped with yellow mustard in 1991. Yields of canola and yellow mustard were significantly reduced when intercropped with peas in both years. The net return analysis suggested that there was no benefit of intercropping in this study, however, the calculation of Land Equivalent Ratio indicated that more land would be required if the crops were to be planted separately. It can be concluded from this study that pea was dominant over yellow mustard and canola and that mustard was a better competitor compared to canola. Intercropping reduced lodging of pea, increased or reduced thousand seed weight of component crops. Nitrogen fertilization had no effect on pea yields in both years.

1.0. INTRODUCTION

There has been a rapidly growing interest in intercropping as a potentially beneficial system of crop production. This system of crop production is common in the tropics but not in temperate climates. Cowell et al., (1989) reported that farmers in western Canada have started intercropping field pea (Pisum sativum L.), here after referred to as pea, with non-legumes in order to facilitate harvest operations and to obtain clean seeds. In 1990, 40.5 thousand hectares of pea were grown in Manitoba and it increased to 72.5 thousand hectares in 1991 (Statistics Canada).

Indeterminate cultivars of pea plants have inherently poor standing ability for a combine harvested crop. The pea crop canopy sags during development and the vines frequently lie flat on the ground at plant maturity. Not only harvest losses can be high but the quality of pea may also be reduced due to soiling and the weathering effects associated with lodging.

Canola (Brassica napus L.) and yellow mustard (Sinapis alba L.), here after referred to as mustard, are major crops grown in western Canada which have strong stems. Intercropping pea with these crops reduces lodging. There are several other possible benefits of intercropping legumes with non-legumes.

In terms of land use efficiency intercropping is regarded as more productive than sole cropping (Andrew and Kassam, 1976; Willey, 1979). Higher nutrient uptake (Dalal, 1974;) and better water use efficiency (Baker and Norman, 1975; Hulugulle and Lal, 1986) have been suggested. Nitrogen fixing legumes generally do not need N fertilizer, whereas, the non-legume requires addition of mineral nitrogen for optimum growth. Accordingly, sufficient nitrogen fertilizer must be applied to support the growth of non-legume. Besides supplying its own nitrogen requirement, legumes may contribute additional nitrogen to the soil which can be used by the component crop in the intercrop or to the succeeding crops. (LaRue and Patterson, 1981).

The objective of this study was to investigate the effects of intercropping field pea with canola or mustard under two levels of nitrogen fertility on canopy development and the final grain yields.

2.0. LITERATURE REVIEW

2.1. Terminology.

There are many terms that are used to describe the growing of two or more crops in a given unit of land in a season which has resulted in confusion on the usage of these terms.

Intercropping is the growing of two or more crops simultaneously on the same area of land. The crops are not necessarily sown at the same time and their harvest times may be quite different, but they are usually simultaneous for a significant part of their growing periods. Willey (1979) defined intercropping as any form of cropping system in which there is some competition between the intercrops.

Andrews and Kassam (1976) published standardized terms which included four main types of intercropping:

Relay intercropping: growing two or more crops simultaneously during part of their life cycles. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Mixed intercropping: growing two or more crops simultaneously with no distinct row arrangement.

Row intercropping: growing two or more crops simultaneously where one or more crops are planted in rows.

Strip intercropping: growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically.

Component crop: refers to either of the individual crops making up the intercropping situation.

Sole crop: refers to a component crop being grown alone and unless otherwise indicated is assumed to be grown at optimum population and spacing.

2.2. Background.

Intercropping has long been recognized as a common practice throughout the developing tropics (Willey, 1979). Early cropping systems were mixtures of desirable species used for food, fibre and other needs in the community (Francis, 1989). Sole cropping is a relatively recent innovation in agriculture. The farmers over the centuries selected mixtures of species to make better use of rainfall and the native soil fertility, and the choices of patterns were made among the best performing combination observed through experience.

Combination of crops are determined by the length of the growing season and the adaptation of crops to particular environments (Ofori and Stern, 1987). In northern Nigeria, early maturing and drought tolerant crops dominate in areas with annual rainfall of less than 600 mm and where the growing season is short (Andrews, 1972; Baker, 1979). In areas with annual rainfall greater than 600 mm, non-legumes and legumes of varying maturities are used. In tropical regions the non-legume component is usually maize, sorghum, millet or rice and the legume is usually cowpea, groundnut, soybean, chickpea, bean or pigeon pea (Ofori and Stern, 1987). It was reported by Baker (1979) that both the early and late maturing crops are combined to ensure efficient utilization of the whole growing season. A common crop combination is maize and cowpea in west Africa (Okigbo and Greenland, 1976) whereas maize and different types of beans dominate in South and Central America (Francis et al, 1976). Combinations of rice and legumes are prevalent in South East Asia (Harwood and Price, 1976). In some temperate regions, with warm climates, intercrop systems consist of wheat, oats, or barley as non-legume component and the field bean, vetch, lupin, or soybean as the legume component (Ofori and Stern, 1987).

Quantitative estimates suggest that 98% of cowpea grown in Africa are intercropped (Anorn, 1972) and 90% of beans in Colombia, and 80% of beans in Brazil are intercropped (Francis et al.,1986). The percentage of the cropland actually devoted to intercropping varies from as low as 17% in India to a high of 94% in Malawi (Vandermeer, 1989). Vandermeer (1989) also indicated that intercropping was common in temperate North America before the widespread use of modern varieties and mechanization. Historically, however, intercropping has been regarded as a primitive form of agriculture which would eventually give way to sole cropping as a natural and inevitable consequence of agricultural development (Willey, 1979).

It has been realized more recently that many intercropping systems persist today on farms on which resources are limited and the level of technology is low. It has also been realized that little improvement of the intercropping situation is likely to result from research which considers only sole crops. Francis (1989) reported that intensive cropping systems often with mixtures of species have reached high yield levels through the use of pesticides, improved cultivars and other high input technology in countries such as China, Taiwan, the Philippines, and Thailand.

Since intercropping is not only a common practice, but there is also a possibility that it can provide yield advantages, research should be strengthened in order to facilitate better understanding of this kind of farming system.

2.3. Advantages of intercropping.

2.3.1 Assessment of advantages.

The evaluation of the advantages of intercropping situations can be difficult. Evaluation of intercropping advantages arises due to difficulties associated with the choice of terms or units in which advantages should be measured (Willey,1985). Willey (1985) attempted to simplify these difficulties by recognizing two distinct objectives in the evaluation process of intercropping. i.e biological and practical objectives.

The biological objective aims at finding out whether there is biological efficiency in intercropping as compared to sole cropping and the units used are usually relative. A common unit used is the Land Equivalent Ratio.

The practical objective embraces the aims and the constraints that determine the amounts of crops to be grown. It was suggested by Willey (1979) that three criteria could be used when considering practical assessments of intercropping advantages.

(i) Where intercropping must give full yield of a main crop and some yield of the second crop. It involves a situation where the primary requirement is for a full yield of some staple food or a commercial crop. A good example of this situation is where the main crop has weak stems and thus needs support in order to avoid lodging and therefore facilitate easy harvesting and to obtain cleaner seeds. It is an easily defined situation since a yield advantage occurs when there is a yield of the second crop and the yield of the main crop is not significantly affected by the second crop.

(2) Where the combined intercrop yield must exceed the higher sole crop yield. This advantage criterion is based on the assumption that unit yield of each component crop is equally acceptable and therefore the requirement is simply for maximum yield regardless of the crop from which it comes. This has been traditionally used to assess advantages in grassland mixtures (Donald, 1963) and for assessing a wider range of intercropping situations (Trenbath, 1974).

(3) Where the combined intercrop yield must exceed a combined sole crop yield. A criterion of this kind considers factors which influence farmers decision making. It assumes that the farmer needs to grow more than one crop in order to guard against market risks, to satisfy dietary needs, to spread labour peaks etc. In this situation yield advantage occurs when intercropping results in higher yields

than growing sole crops separately. It is the commonest situation in practice.

The practical objective is evaluated depending on the purpose for which the crops are crown. The units of measurement can be in monetary, nutritional, relative or absolute values.

2.3.1.1. Land Equivalent Ratio

The land equivalent ratio (LER) is the measurement most frequently used to evaluate both the biological and the practical objectives of intercropping advantages (Mead and Willey, 1980). LER is defined as the relative land area under sole crops that is required to produce the yields achieved in intercropping. When LER = 1, there is no intercropping advantage in comparison to sole cropping. A LER which is greater than unity implies that a larger area of land is required to produce same yield of sole crop of each component grown separately than an intercropped mixture. For example, when the LER = 1.15, then 15% more land is needed to produce the same yield from the component crops in sole stands.

The value of LER is influenced by several factors including competitive ability of component crops, duration of growth, and the agronomic factors that affect the growth and development of individual crop species (Natarajan and Willey, 1980; Fawusi et al., 1982).

Willey (1979) recommended that LER values be presented along with absolute yields because the practical significance can only be fully assessed when related to the actual yields.

2.3.2.0. Efficiency of resource use

2.3.2.1. Competition and yield advantages

One cause of yield advantage of intercropping documented in the literature is better use of resources. Francis (1989) reported that although relationships between and among crop species grown in mixture have been described, results have most often been expressed in final yield and on occasion total dry matter. Yield is a valid indicator of the competitiveness of that component for the scarce growth resources under any given set of conditions.

Terms have been developed to describe the partitioning of inter and intra-specific competition (Hill and Shimamoto, 1973; Trenbath, 1974). Willey (1979) attempted to simplify the types of competition by recognising three broad categories of interactions that affect intercrop yields. The first category is a situation where the actual yield of each species is less than when grown alone. Yield response in this category is rare in the field situation but a few cases have been reported (Allgren and Aamodt, 1939; Donald, 1946; Harper, 1961).

The second category is a situation in which each species produces more when two crops are planted together, than when planted alone. The third category, and most common is termed compensation. In this situation one crop produces more and the other produces less than as sole crop. Relationship of this kind involves a more competitive crop (dominant) and a less competitive (dominated) crop in the mixture (Huxley and Maingu, 1978).

2.3.2.2. Light use

Solar energy cannot be captured and stored for later use in the way that other natural resources are managed. Light is instantaneously available and needs to be instantaneously intercepted and used if this resource is going to be useful to produce photosynthate and plant dry matter (Donald, 1961). Competition for light is between leaves rather than between plants, and a leaf that receives below the compensation point will soon perish (Etherington, 1976). Plants that are favoured in the mixture are not necessarily those with the most leaves and foliage, but those with the leaves in the best position to intercept solar radiation (Francis, 1989). If water and nutrient requirements of crops are met, then light is most frequently the limiting resource (Willey, 1979).

Trenbath (1976) reported that both photosynthesis and plant growth of each component crop will be proportional to the amount of radiation that each component intercepts. There are both temporal and spatial ways in which multiple cropping systems use light more efficiently than sole crops. A mixture of crops may cover the ground over a greater portion of the year and thus intercept more light. It was concluded by Willey and Roberts (1976) that light energy was often the most important factor in over yielding by crop mixtures that exhibited temporal complementarity.

The amount of light intercepted over the entire growing season is primarily the function of leaf area duration (LAD) of one or more of crops developing the canopy. Zandstra (1978) observed that although the LAD of each of the intercrop components is reduced, the overall LAD of the mixed canopy can be greatly increased. This increased LAD for the growing season is particularly true for relay intercropping.

Intercrops have potential to intercept light in different ways than sole crops (Francis, 1989). Intercrops may involve crops with dissimilar growth habits. The differences in growth habits results in a better vertical distribution of leaves in the intercrop canopy. Component crops with similar morphology may compete severely for growth factors.

Regnier et al. (1989) reported that common cocklebur competed strongly with soybeans because its growth in height is similar to soybeans and both species develop lower leaf canopy under shaded conditions. Common cocklebur and soybeans thus exploit the same above ground environment and are in direct competition for light and space within the canopy.

The inclination of the leaves influence the amount of light which is intercepted by the canopy of the tall component and hence the amount which is available to the short component. A tall crop, especially a cereal with C_4 light response intercropped with a shorter dense crop with C_3 response could enhance the total light use (Crookston and Hill, 1979). Willey (1979) concluded that better spatial use of light could be achieved through more efficient use of light rather than greater light interception and could hold the most promise for further increasing yield potential of crop mixtures.

Natarajan and Willey (1980) found that in a sorghum-pigeon pea combination the amount of light intercepted relative to incoming incident radiation at 55 days was 84% in sole crop of sorghum, 65% in sole crop of pigeon pea and 80% in the intercrop mixture. In a maize-pigeon pea intercrop system, interception of light was low with the slow increase in leaf area index in a maize-pigeonpea intercrop system and above 80% when the leaf area index reached about three (Sivakumar and Virmani, 1980). They also observed that the intercrop system attained LAI of three in 45 days, compared to 50 days in sole crop of maize and 115 days in sole of pigeon pea.

The energy conversion efficiency, defined by the dry matter produced per unit of light energy absorbed, of groundnut-millet intercrop was higher than in sole stand at maximum leaf area index (Marshall and Willey, 1983).

2.3.2.3. Nutrients and Water use

The use of water by a crop mixture provides a condition under which competition for a limited resource might occur. Water, as a resource, interacts with many other plant growth factors. Water is often the most limiting factor in crop growth, especially in the tropics, and thus the ability of roots to explore a large soil volume and extract water is critical (Etherington,1976). Intercrops may be more efficient in exploring a larger soil total volume if the component crops have different rooting habits (Willey,1979). There is evidence from a number of studies that a deeper rooting component crop may be forced to develop even deeper roots if grown together with shallow rooted crops (Whittington, and O'Brien,1968; Fisher, 1976). Where moisture is the most limiting resource, intercrops may offer both a temporal and spatial advantage in water use (Baker and Norman,1975).

Mobility of soluble ions such as nitrate is the same as that of water in the soil and roots may attract nitrates from as much as 25 cm away in the soil solution (Trenbath, 1976). Nutrients such as ammonium, calcium, phosphorous, and potassium are strongly held on surfaces of soil particles and are present in low concentrations in the soil solution and they move almost entirely by diffusion. The ability of an intercrop to make more efficient use than sole crops of soluble and non soluble nutrients depends on the extent of root growth of component species, soil water levels, and how completely the intercrop mixture explores the entire soil mass in the rooting zone. Biological efficiency is likely to result when the intercrops explore a larger soil volume or explores the same soil mass more completely compared to sole plantings of the same species. There is also a possibility of differences in time of peak demand for different nutrient elements by components in the mixture (Willey, 1979).

Higher total nutrient uptake by intercrops than sole crops has been reported (Dalal, 1974; Hall, 1974). Differences in total yield by intercrops has been explained by greater nutrient uptake (Willey,1979). Baker and Blaney (1988) reported that uptake of nitrogen by sorghum-soybean intercrop was less compared to sole cropped sorghum but intercropping still produced significantly higher yields than sole cropping. Competition for nutrients, especially in pasture mixtures was reviewed by Haynes (1980). He concluded that legumes in general are poor competitors with grass species for nitrogen. Rates of nutrient uptake vary with plant age, and the period of maximum nutrient demand for one species may not coincide with that of the other species in the intercrop. Dalal (1974) observed that dry matter production by pigeonpea in a corn-pigeonpea intercrop was less than 50% of sole pigeonpea during the first 16 weeks but the growth of pigeonpea between 16 and 24 weeks was enough to produce seed yields similar to the sole crop. The pattern of nutrient uptake for a particular crop may change when placed in direct competition with another species.

Nitrogen transfer from legumes to associated non-legume is often mentioned as a potential benefit of cereal-legume intercrops (Aggarwal et al., 1992). Giller et al. (1991) reported small but significant increases in total N yield in maize intercropped with N^2 fixing bean compared to maize intercropped with non-nodulating bean. However, Hamel et al. (1991) using ^{15}N dilution method found no evidence of N transfer between soybean and maize plants.

2.3.2.4. Pest management

Although there is little information from literature in intercropping systems regarding insect pests and weeds, it is generally agreed that with two or more crops in an intercropping system, insect pests are reduced and weed competition is reduced (Francis, 1989). Litsinger and Moody (1976) reported that there are large differences among species in competitive ability with weeds. The differences in competitive abilities are due to variations in plant characteristics, environment, and the relative emergence dates. Shading of the soil and the competition for nutrients and water will suppress weed germination and growth (Alteiri and Liebman, 1986). Alteiri and Liebman (1986) reviewed the literature and described intercropping systems in which insect pest were less prevalent than in the constituent sole crops.

In an intercrop combination, there is a mixture of susceptible and resistant plants to plant diseases. The result is that the distance between two susceptible plants is increased and so the disease spread is reduced. In certain intercrops, the presence of pathogens can lead to LER>1 and thus, possibly to overyielding (Trenbath, 1976). The reasons advanced for this observation include the settling of pathogens on non-host components and the compensating growth by the components which are not attacked. However, there may be intercropping situations that affect the microclimate of the canopy and thus favour greater disease incidence.

2.3.2.5. Physical support

Erect growing crops species may provide support for intercropped climbing species. The support allows the climbing species to achieve greater vertical separation of the leaves which may improve the photosynthetic effectiveness of the leaf area of the climbers (Trenbath and Angus, 1975). Erect winter wheat allowed the peas to remain more upright, creating a better canopy for light capture (Murray and

Swensen, 1985). The non-lodging component crop may hold up the lodging susceptible component if they are intercropped. Cowell et al., (1989) reported a reduction in the lodging of pea when it was intercropped with rape, mustard, or oats.

2.3.2.6. Economic aspect of intercropping

Intercropping systems may not always be more profitable than sole cropping. The profitability of intercropping depends on the yields realized, the relative prices, and the costs of the inputs. Net income advantages appear to be secondary to risk reduction in intercropping systems where the main aim is to meet the subsistence requirements (Lynam et al, 1986). The same authors attributed the sources of reduced risk in intercropping as compared to sole cropping to both reduced variance in output and/or the net income and the higher profitability of avoiding complete crop failure.

Crop diversification is another strategy that farmers can use to reduce risks. Crop diversification is defined in this case as the planting of several crops on the same piece of land without interplanting. However, intercropping may give more yield stability than diversification due to better utilization of growth resources by component crops and by the insulation of the intercrops to the spread of pests and diseases.

2.4. Disadvantages of intercropping

Intercropping can be disadvantageous in a number of ways. It can take the form of yield losses because of the competition effects. Willey (1979) suggests that such effects are likely to be rare. Competition is defined as the situation in which each of the two or more plants growing together in the same area seek the same growth factor which is below their combined demands (Donald, 1963). The efficiency of production in intercrop systems could be improved by minimizing interspecific competition between component crops for growth limiting factors. Growing component crops with contrasting maturities so that they complement each other rather than compete for the same growth resources at the same time is one way of reducing interspecific competition. (Ofori and Stern, 1987).

Competition between component crops for growth limiting factors is regulated by crop characteristics and agronomic factors (Trenbath, 1976). The crop component with relatively higher growth rate, height advantage, and a more extensive rooting system is favoured in the competition.

It is generally agreed that when interspecific competition for limiting growth factors is less than intraspecific competition for the same growth factor, there is a potential for higher total production in the intercrop system (Andrews, 1972; Willey, 1979).

Allelopathic effects may also occur (Rice, 1974). Rice (1974) defined allelopathy as any direct or indirect harmful effect that one plant has on another through the production of chemical compounds that escape to the environment.

A serious disadvantage of intercropping is associated with mechanization, fertilization, herbicide, fungicide, and insecticides use (Willey, 1979). Planting and harvesting of intercrops could be problematic because the adjustments in the current machinery in the market facilitate planting or harvesting of sole planted crops. Murray and Swensen (1985) indicated that lack of mechanized technology to plant and to harvest interseeded crops has limited adoption in the U.S.A.

Registered herbicides which could be used with the intercrops may not be available. Regarding the insecticides and fungicides, it would be costly to control insect and diseases because two or more pesticides would be required.

Intercrops nutrient requirements could be different both in time and amounts. Increased N fertilizer application in intercrops can have negative effect on the yield of field peas (Anderson et al.,1981; Cowell et al., 1989). Addition of N fertilizer tend to favour the canopy development of the non-legume which may result in severe competition with the legume. The implication then, is that balanced fertilization and proper timing would be essential.

2.5. Agronomy of intercrops

The productivity and efficiency of intercrop systems are affected by various agronomic factors that affect crop yields. Such factors include component crop density, plant arrangement and spacing, relative time of planting and the effect of applied nutrients especially nitrogen in cases where the system involves a legume and a non-legume.

2.5.1. Plant population

Plant population is defined by the number of plants per unit area. For the intercropping situation plant population is more complex. Willey and Osiru (1972) pointed out that in terms of the plant population pressure on resources a single plant of one crop is seldom directly comparable to a single plant of another crop. Component populations determine how much of the yield is contributed by each crop making up the intercropping situation (Willey,1979; Osiru and Willey,1972). The contribution by each component depend on their competitive abilities and other factors which influence them (Osiru and Willey,1972).

2.5.2. Plant arrangement and spacing

Arrangement of component crops influences the amount of light that is transmitted to the component crop with lower canopy. Ofori and Stern (1987) indicated that row arrangements improves the amount of light transmitted to the lower component crop than arrangements of component crops within rows. In maize-pigeonpea intercrop system maize yield was reduced by 20% when pigeonpea was in the same row (Dalal, 1974). Agboola and Fayemi (1971), however, did not find any difference whether maize and cowpea were planted in the same or alternate rows.

2.5.3. Planting time

The time of planting may depend on the objectives for which the intercropping is intended to achieve. When component crops of different maturities are sown at the same time yield advantages occur but if the early maturing component is sown later yield advantages diminishes (Baker and Francis,1986; Willey,1979). The advantages are reduced due to the fact that earlier sown crop becomes more competitive than when they are sown simultaneously (Baker and Francis,1986)

2.5.4. Response to nutrient and water

The response of crop species to nutrients may differ markedly. It is, therefore, appropriate to know the nutritional requirements and the growth characteristic of the crops which are to be grown in an intercropping situation. Hall (1974) observed that without added potassium, the growth of Desmodium was severely reduced in the mixtures with Nandi seteria relative to its growth in sole stands.

There is a belief that advantages of intercropping may occur only in low fertility situations simply because intercropping is abundantly practised in poorly developed agriculture. Willey (1979) believes that where advantages depend on temporal differences between component crops, it will occur even at higher productivity levels.

Ahmed and Rao (1982) reported that component crops respond to applied nitrogen differently in different non-legume and legume combinations. Apart from light, nitrogen is the main factor influencing the production efficiency of non-legume intercropping systems (Ofori and Stern, 1987). Ezumah et al. (1987), while working on maize-cowpea intercrops, observed that an early maturing determinate, semi-erect cultivar of cowpea did not respond to applied nitrogen, whereas, the yield of the indeterminate, photoperiod sensitive, spreading cultivar decreased with increasing nitrogen fertilization. With increasing availability of N from other sources the dependence on atmospheric N_2 by the legume decreases (Ofori and Stern, 1987). The applied N has the negative effect of affecting the infection of legume roots by the rhizobium, the nitrogenase activity and the nodule mass (Streeter, 1988).

MATERIALS AND METHODS

3.1. Treatments and management

Field studies were conducted during the summers of 1990 and 1991 at the University of Manitoba, Plant Science Field Research Station at Portage la Prairie, Manitoba, approximately 70 km west of Winnipeg. Soil types in the experimental area were fine clayey montmorillonitic (calcareous) Aquic haploboroll (Dugas clay) in 1990 and montmorillonitic (calcareous) Aquic udifluvent (Fortier silty clay) in 1991 (Michalyna and Smith, 1972). In both years, the experiments were planted on wheat stubble.

Trifluralin (Treflan 5G[1]), a residual type herbicide was applied in the fall preceding each experimental year in order to control weeds. Treflan 5G was applied at the rate of 34 kg/ha. The herbicide was incorporated twice using a disc harrow to a depth of 10 cm, first in one direction and then at right angle to the first harrowing.

In 1990, the experiment was laid out in a split block design replicated four times. It consisted of two main plots and eight sub-plot treatments. The 1991 experiment was also laid out as a split block, replicated six times, and it consisted of two main plots and eleven sub-plot treatments. The main plots consisted of 0 and 90 kg/ha of N fertilizer in

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[1] Treflan 5G is a 5% a.i. granular formulation (Dow-Elanco)

both years. The ammoniun nitrate fertilizer (34:0:0) was broadcasted using fertilizer spreader on May 8 in 1990 and May 14. in 1991. The subplot size was 12 m by 1.83 m in both years. The main plot treatment plots measured 24 m by 12 m in both years. All the treatments were assigned to the plots randomly.

Tables 3.1. Shows the projected seeding rates of the cropping system treatment used in 1990 and 1991. The seeding rate used were based on the optimum seed rate recommendation for peas, mustard and canola. In the mixtures, the replacement series technique was used in this study. In the replacement series technique the proportion of one crop species was replaced by another.

Table 3.1. Projected seeding rates of canola, pea, and mustard used. (1990 and 1991).

	Seeding rate (kg/ha)		
Cropping system	Pea	canola	Mustard
Sole pea	180	-	-
Sole pea	120	-	-
Sole canola	-	6	-
Sole canola	-	2	-
Pea/canola intercrop	120	2	-
Sole mustard	-	-	9
Sole mustard	-	-	3
Pea/mustard intercrop	120	-	3

In 1990, the germination of the non-legume crops were poor, and coupled with flea beetle damage, the plant counts were far below the required optimum, therefore, the experiment was replanted. The same plot area was used. The plots were sprayed with glyphosate[2] on 1st of June 1990 so as to kill the previous crop plants. The glyphosate was applied at the rate of 1.0 l/acre using CO_2 pressurized sprayer. Due to the poor emergence and flea beetle damage experienced from the first planting, higher seed rates were used so as to obtain uniform stands of pea, mustard, and canola in sole crops and in crop mixtures.

The actual seeding rates used in 1990 were 216 and 144 kg/ha for peas, 7.2 and 2.4 kg/ha for canola, and 10.8 and 3.6 kg/ha for mustard. In 1991, the seeding rate were 198 and 132 kg/ha for peas, 6.6 and 2.2 kg/ha for canola, and 9.9 and 3.3 kg/ha for mustard.

To obtain the plant densities that would have resulted from the seeding rates shown in Table 3.1, thinning was carried out when it was ascertained that all the emergence was complete and before competition was apparent (20 DAP). The average post-thinning densities (plants/m^2) were 73 and 55 pea, 94 and 44 canola, and 82 and 35 mustard in 1990. There were 57 and 44 pea, 118 and 47 canola, and 84 and 33 Mustard plants in 1991.

Canola, mustard and pea were sown using a drill equipped with double disk openers and a cone seeder was used to plant pea and canola or mustard simultaneously at the beginning of June in 1990 and the second week of May in 1991. In intercropped treatments component crops were seeded on the

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[2] N-(phosphonomethyl)glycine (MONSANTO)

same row. Planting was adjusted to a depth of 2-2.5 cm. The double disk openers were separated at 15 cm spacings. Mono-ammonium phosphate was applied at the rate of 35 kg/ha at planting time. In 1990, 'Westar' canola, 'Gisilba' mustard, and 'Century' pea were used as test crops. 'Westar' canola was replaced with Legend cultivar and 'Century' pea was replaced with Bohatyr cultivar in 1991. Century pea was replaced with Bohatyr pea because it regreened late in the season in 1990. Bohatyr pea is a more determinate cultivar that matures earlier than Century pea. Westar canola was replaced with Legend canola because Legend cultivar is more resistant to blackleg. Blackleg attacks the base of the stem hence causing lodging of the crop.

In order to control insect pest damage, seeds of canola and mustard were treated with Vitavax RS[3] at the rate of 22.5 ml/kg of seed and Furadan[4] at the rate of 4.5 kg/ha in 1990.

In 1991 Premiere[5] was used at the rate of 28 ml/kg of seed instead of Vitavax RS. Pea seed was inoculated with Nitragin 'C'[6] rhizobium inoculant just before planting. Inoculation was achieved by wetting the seed with sugar solution before applying the inoculant dust.

Post emergence flea beetle control measure was achieved

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[3] Vitavax RS contains Carbathiin, Thiram, and Lindane.

[4] systemic insecticide by Chemgro corp.

[5] Primiere contains Thiram, Thiabendazole, and Lindane

[6] product by LiphaTech, Milwaukee

by the application of Decis 5Ec[7] four times at the rate of 150 mls of the product per hectare.

Sethoxydim[8] (Poast), a grass herbicide, was applied on 12th June 1991 to control volunteer wheat and wild oats. Poast was applied at the rate of 2.8 l/ha plus a surfactant. In both years, hand removal of broad leaf weeds was done when it was necessary.

In both years, Spodnam[9] was applied to the plots to prevent the shattering of canola and pea three weeks before harvesting.

In 1990, there was regrowth by the Century pea when the other crop species were completely dry, and so Reglone[10] was applied to desiccate the peas.

Canopy heights were measured on 15th August in 1990 and in 1991 canopy height was measured twice, first on June 20th and later on July 8th.

3.2. Sampling and data analysis

Dry matter yields of above ground plant parts were determined 29, 43, and 64 days after planting (DAP) in 1990 and 26, 42, and 55 DAP in 1991. Plants from 0.25 m^2 quadrat

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[7] Deltamethrin (HOECHST)

[8] 184 g/l EC (BASF)

[9] Polymer of cyclohexane, Trade Mark of Mandops Inc. Lake Park, Florida

[10] Diquat 200 g/L SN (ICI)

were harvested, separated to individual plant species counted and then bagged ready for oven drying. The plants were oven dried to a constant weight at 70C for at least 60 hours.

Leaf Area Indices (LAI) were determined 32, 39, and 46 DAP in 1990 and 30, 36, 44, and 52 DAP in 1991. LAI measurements were achieved by using non destructive method which utilizes LAI-2000[11] Plant canopy Analyzer. LAI-2000 is an electronic equipment which measures LAI by comparing light transmittance above and under the canopy (Welles and Norman, 1991).

When the crops were ready to be harvested, lodging was scored on each subplot. The crops were harvested using Wintersteiger plot combine harvester. Adjustments were made to facilitate the harvesting of the intercrops. The yields of the intercrops were separated, cleaned and weighed. Thousand seed weights were also determined.

To compare the productivity of each species when intercropped vs sole cropped, Land Equivalent Ratio (LER) was used. LER values were calculated as; LER=A+B, where A and B are the fractions of dry matter or grain yield of intercropped pea and canola or mustard relative to the yield of their sole crops.

i.e $$LER = \frac{IC(pea)}{SC(pea)} + \frac{IC(canola\ or\ mustard)}{SC(canola\ or\ mustard)}$$

Where IC = intercropped and SC = sole cropped.

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[11] product of LI-COR, Inc., Lincoln, Nebraska, U.S.A

The cost effectiveness of each treatment was determined as the differences between the calculated value of the yield and the variable cost per hectare. Fixed costs, defined in this case as those costs which are the same for every treatment were not included in the calculations. The variable cost included N fertilizer, inoculant, seed treatments, separation and cleaning, and seed.

Table 3.3 below shows the prices that were use in the calculation of the net return.

Table 3.3. Net return grain prices and input costs.

Grain prices.

Canola	$320/tonne
Mustard	$330/tonne
Pea	$184/tonne

Seed costs

Gisilba mustard	$1.19/kg
Legend canola	$1.98/kg
Westar canola	$2.09/kg
Century pea	$0.37/kg
Bohatyr pea	$0.32/kg
pea inoculum	$1.25/ha

Fertilizer costs.

Nitrogen	$0.55/kg

Herbicide costs.

Trifluralin	$39.52/ha

Cleaning costs.

Pea + mustard (canola)	$10.00/tonne

Data were analyzed using analysis of variance procedures (Statistical Analysis Systems) and when the F values were significant, means were separated by LSD(0.05). Correlations between leaf area indices, total dry matter and total grain yield were determined. The plant counts for the extra treatments in 1991 were very low, therefore, the data from these treatments were not included.

4.0. RESULTS AND DISCUSSION

4.1. Crop establishment and phenology.

There was no apparent influence of pea on the phenological development of canola and mustard. Canola and mustard emerged 9 DAP but the pea emerged 12 DAP in 1990. In 1991, canola and mustard emerged 6 DAP while pea emerged 8 DAP. Although canola and mustard emerged earlier than pea, their early growth was not vigorous enough as to suppress the later emerging pea. Differences in the emergence date did not affect the competitiveness of pea. In 1990 and 1991 mustard attained 50% flowering four and seven days earlier than canola, respectively. The difference observed in this case could be due the cultivar differences since the canola cultivar was different in 1991 or due the differences in environmental conditions. It was warmer in 1991 than it was in 1990 (Table A1).

In both years, the mustard phenologically developed faster than canola such that at the time when pea overtopped the mustard, it had already completed flowering, whereas, canola was overtopped while flowering was in progress.

Many pea cultivars, canola, and mustard have indeterminate growth habit. Flowering starts from the lower branches and progresses upwards. The flowering of pea was difficult to asses because of pea bushy robust indeterminate growth habit. However, there was no noticeable difference between pea in sole stands and the pea intercropped with canola or mustard. Temporal differences in phenological development of intercrops is essential if serious competition for growth resources by the component crops is to be avoided. The differences in phenological development implies that there would be no serious competition during important vegetative and reproductive stages which may translate to good yields.

4.2. Dry matter accumulation.

In 1990, the dry matter accumulation of the Century pea when intercropped with Westar canola or Gisilba mustard was not significantly influenced as compared to the sole planted treatments at the same seeding rate (Tables 4.1 - 4.3). The dry matter production by Century pea was not reduced because it was more competitive than canola or mustard.

Table 4.1. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 29 DAP, 1990.

Treatments	Canola	Mustard	Pea	Total
	Mean* dry matter yields (g/m^2)			
Sole pea (180 kg/ha)	-	-	95.6a	95.6a[Υ]
Sole pea (120 kg/ha)	-	-	69.4ab	69.4c
Sole canola (2 kg/ha)	36.0a	-	-	36.0d
Sole canola (6 kg/ha)	47.0a	-	-	47.0cd
Pea + canola(120 + 2kg/ha)	20.0b	-	61.6b	81.7ab
Sole mustard (3 kg/ha)	-	63.2a	-	63.2bc
Sole mustard (9 kg/ha)	-	74.4a	-	74.4abc
Pea + mustard (120 + 3 kg/ha)	-	23.7b	47.9b	71.6abc

[Υ] Values in a column followed by the same letter are not significantly different at 5% level.
* Mean of eight plots of both nitrogen levels.

Table 4.2. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 43 DAP, 1990.

Treatments	Canola	Mustard	Pea	Total
	Mean* dry matter yield (g/m^2)			
Sole pea (180 kg/ha)	-	-	318.1a	318.0a[1]
Sole pea (120 kg/ha)	-	-	277.9a	277.9a
Sole canola (2 kg/ha)	285.1a	-	-	285.1a
Sole canola (6 kg/ha)	296.2a	-	-	296.2a
Pea + canola (120 + 2 kg/ha)	70.0b	-	287.4a	357.4a
Sole mustard (3 kg/ha)	-	370.0a	-	284.2a
Sole mustard (9 kg/ha)	-	284.2a	-	370.0a
Pea + canola (120 + 3 kg/ha)	-	89.4b	288.0a	377.4a

[1] Values in a column followed by the same letter are not significantly different at LSD 0.05 level.
* Mean of eight plots of both nitrogen levels.

Table 4.3. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 64 DAP, 1990.

Treatments	Canola	Mustard	Pea	Total
	Mean* dry matter yield (g/m^2)			
Sole pea (180 kg/ha)	-	-	474.4a	474.4a[1]
Sole pea (120 kg/ha)	-	-	531.4a	531.4ab
Sole canola (2 kg/ha)	642.1a	-	-	642.1a
Sole canola (6 kg/ha)	675.3a	-	-	675.3a
Pea + canola (120 + 2 kg/ha)	168.0b	-	477.0a	645.0a
Sole mustard (3 kg/ha)	-	627.1a	-	627.1ab
Sole mustard (9 kg/ha)	-	674.3a	-	674.3a
Pea + mustard (120 + 3 kg/ha)	-	135.7b	476.0a	611.7ab

[1] Values in a column followed by the same letter are not significantly different at LSD 0.05 level.
* Mean of eight plots of both nitrogen levels.

When Gisilba mustard was intercropped, its dry matter accumulation was significantly reduced compared to when it was grown as a sole crop (Tables 4.1 - 4.3 and Fig. 4.1a and 4.1b). The dry matter yield of mustard intercropped with Century pea was reduced by 68%, 76%, and 79% at 29, 43, and 64 DAP, respectively, compared to the dry matter produced by sole mustard. The reduction of seeding rate by two thirds did not significantly affect the dry matter accumulation as compared to that seeded at full rate when mustard was grown in sole stands. No differences in dry matter accumulation was observed because of compensation by mustard plants when seeded at low density.

The dry matter accumulation of Westar canola was significantly reduced when it was grown in association with Century pea (Fig 4.2a and 4.2b, and Tables 4.1 - 4.3). The dry matter yield by canola intercropped with Century pea was reduced by 62, 77, and 76% at 29, 43, and 64 DAP, respectively.

The dry matter accumulation of Westar canola sown as sole crop at 2 kg/ha and that sown at 6 kg/ha was similar. Based on this study it would appear that the optimum plant density was attained with a seeding rate of 2 kg/ha. (Fig.4.2a and 4.2b).

In terms of total dry matter production, there were significant differences between treatments at the first sampling date (29 DAP) but there was no difference at the second sampling date (43 DAP). However, at 64 DAP sampling date significant dry matter differences were observed.

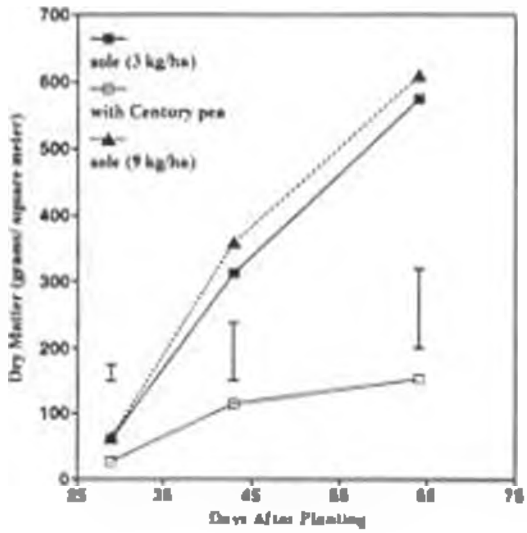

Fig 4.1a Dry matter production by mustard in sole croppping and when intercropped with Century pea in 1990 with no nitrogen added

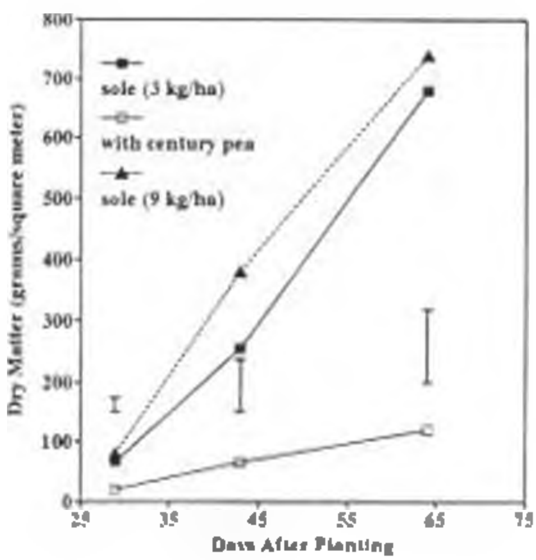

Fig. 4.1 Dry matter production by mustard in sole cropping and when intercropped with Century pea with 90 kg/ha of nitrogen added in 1990

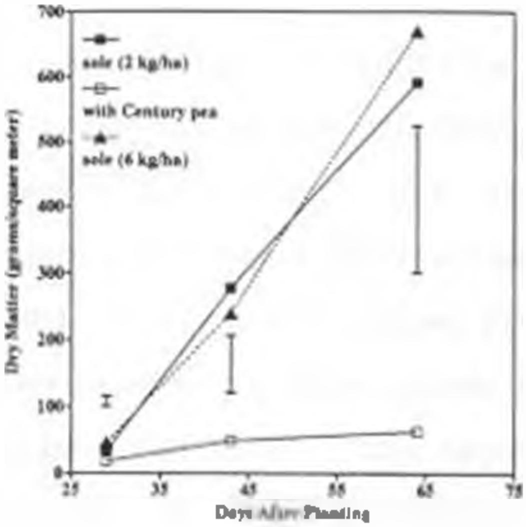

Fig. 4.2a Dry matter production by Westar canola in sole cropping and when intercropped with Century pea with no nitrogen added in 1990.

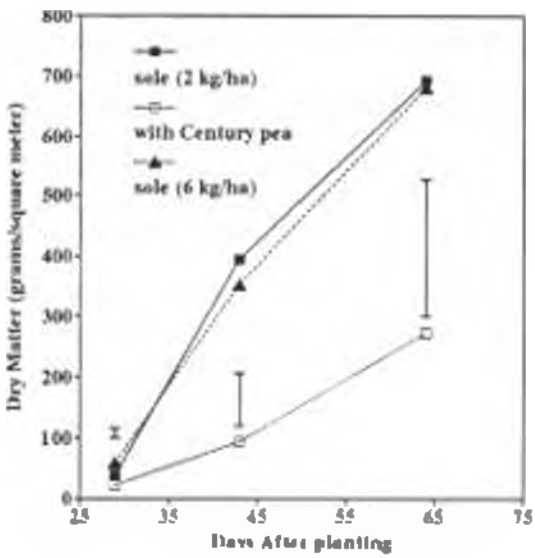

Fig. 4.2b Dry matter production by Westar canola in sole croppping and when intercropped with Century pea with 90 kg/ha of nitrogen added in 1990.

The application of 90 kg/ha of nitrogen fertilizer did not significantly affect the growth and hence the dry matter accumulation of Century pea (Table 4.4). Although not significant, the dry matter accumulation of Century pea was higher when it was intercropped with Westar canola and mustard than when planted in sole stands without nitrogen fertilizer application (Fig.4.3a). The opposite trend occurred when 90 kg/ha of nitrogen fertilizer was applied (Fig.4.3b). The application of nitrogen appears to favour the competitiveness of canola and mustard in the intercrop. On the other hand when no nitrogen was applied, the Century pea was probably placed in a favourable situation in that the support from canola and mustard placed the leaves of Century pea in a good position to trap light energy and this coupled with the pea ability to fix atmospheric nitrogen enabled the Century pea to compete well when intercropped with canola or mustard.

Table 4.4. Nitrogen fertilizer effects on dry matter production of pea, mustard, canola and their intercrops, 1990.

Crop	N level	Days After Planting		
		29	43	64
		Dry matter yield (g/m^2)		
mustard	0	49.6a	261.8a	444.8a[1]
	90	55.4a	233.9a	471.5a
Canola	0	24.8a	188.6a	441.5a
	90	32.1a	245.0a	549.1a
Pea	0	70.8a	285.5a	458.1a
	90	66.5a	300.2a	527.9a

[1] Values in column for each crop followed by the same letter are not significantly different at LSD 0.05 level.

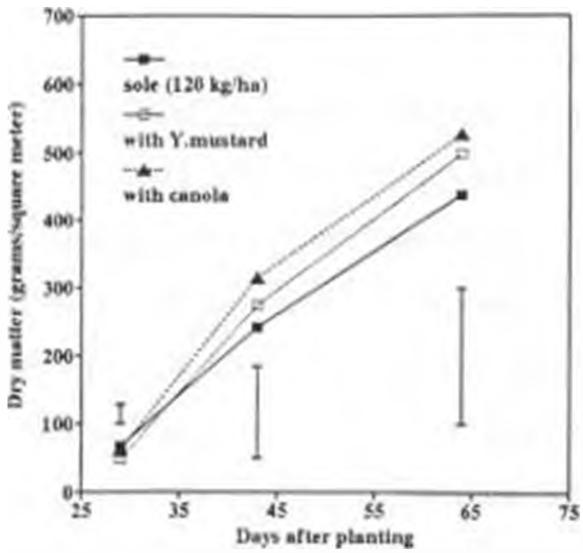

Fig. 4.3a . Dry matter production by Century pea in sole cropping and when intercropped with canola or mustard in 1990 with no nitrogen added.

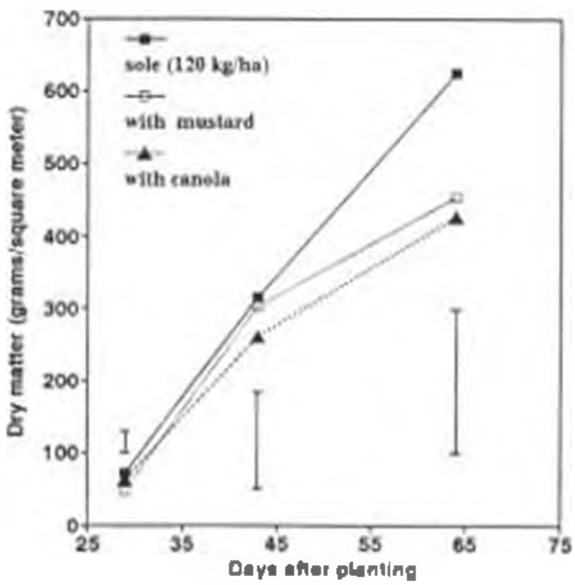

Fig. 4.3b Dry matter production by Century pea in sole cropping and when intercropped with canola or mustard in 1990 with 90 kg/ha of nitrogen added.

Murray and Swensen (1985) reported that erect winter cereals allowed the pea to remain upright, hence creating a better canopy for light capture.

With no N fertilizer added, dry matter accumulation by Gisilba mustard was similar for the two seeding rates used as sole treatments. Addition of nitrogen fertilizer had little influence on the competitiveness of mustard.

In 1991, there were significant differences in terms of the dry matter accumulation by pea (c.v Bohatyr) when it was grown in association with canola or mustard compared to when grown as a sole crop (Table 4.5-4.7). As a sole crop, Bohatyr pea accumulated dry matter at a higher rate than when it was intercropped with Legend canola and Gisilba mustard (Fig.4.4a and 4.4b). Although not significant the competition stress appears to have been more severe when pea was grown in association with Gisilba mustard. (Tables 4.5 and 4.7). The dry matter production by Bohatyr pea was reduced by 19, 38, 51% and 19, 52, 59% when it was intercropped with canola and mustard at 26, 42, and 55 DAP, respectively in 1991.

Bohatyr pea accumulated dry matter at a slow rate when it was intercropped with Legend canola until 42 DAP after which Bohatyr pea appears to have been more competitive. The behaviour of Bohatyr pea when intercropped differed with Century pea. It has been shown that pea cultivars may respond differently to the intercropping situation (Liebman, 1989).

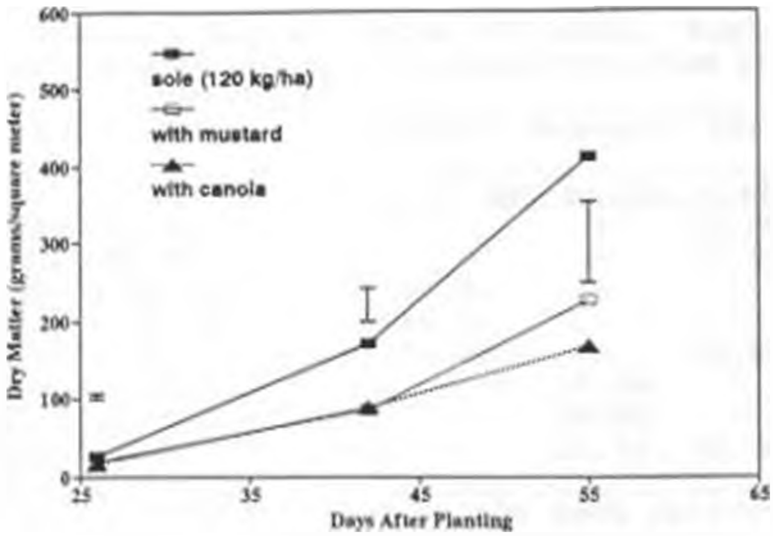

Fig 4.4a Dry matter production by Bohatyr pea in sole cropping and when intercropped with canola or yellow mustard with no nitrogen added

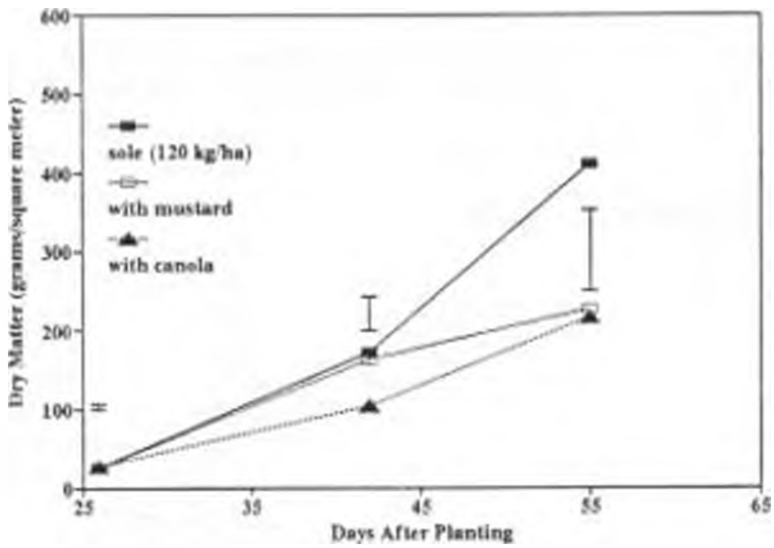

Fig 4.4b. Dry matter production by Bohatyr pea in sole cropping and when intercropped with canola or yellow mustard in 1991 with 90 kg/ha of nitrogen added.

Table 4.5. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 26 DAP, 1991.

Treatments	Canola	Mustard	Pea	Total
	Mean* dry matter yields (g/m²)			
Sole pea (180 kg/ha)	-	-	32.9a	32.9cd[1]
Sole pea (120 kg/ha)	-	-	27.0ab	27.0e
Sole canola (2 kg/ha)	24.8a	-	-	24.8e
Sole canola (6 kg/ha)	48.9b	-	-	48.9b
Pea + canola (120 + 2 kg/ha)	11.6c	-	22.0b	33.6cd
Sole mustard (3 kg/ha)	-	37.5a	-	37.5c
Sole mustard (9 kg/ha)	-	66.8b	-	66.8a
Pea + mustard (120 + 3 kg/ha)	-	21.7c	22.0b	43.7b

[1] Values in a column followed by the same letter are not significantly different at LSD 0.05 level.
* Mean of eight plots of both nitrogen levels.

Table 4.6. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 42 DAP, 1991.

Treatments	Canola	Mustard	Pea	Total
	Mean* Dry Matter Yield (g/m²)			
Sole pea (180 kg/ha)	-	-	234.3a	234.2bc[1]
Sole pea (120 kg/ha)	-	-	200.8a	200.8c
Sole canola (2 kg/ha)	231.3a	-	-	231.3bc
Sole canola (6 kg/ha)	288.6b	-	-	288.6a
Pea + canola (120 +2 kg/ha)	153.5c	-	124.4b	276.9ab
Sole mustard (3 kg/ha)	-	316.3a	-	316.3a
Sole mustard (9 kg/ha)	-	300.4a	-	300.4a
Pea + mustard (120 + 3 kg/ha)	-	206.9b	96.6b	303.5a

1 Values in a column followed by the same letter are not significantly different at LSD 0.05 level.
* Mean of eight plots of both nitrogen levels.

Table 4.7. Mean dry matter yields of canola, mustard and pea in sole stands and intercropped harvested 55 DAP, 1991.

Treatments	Canola	Mustard	Pea	Total
	Mean* dry matter yield (g/m²)			
Sole pea (180 kg/ha)	-	-	423.0a	423.0a†
Sole pea (120 kg/ha)	-	-	459.9a	459.9a
Sole canola (2 kg/ha)	399.1a	-	-	399.1a
Sole canola (6 kg/ha)	389.9a	-	-	389.9a
Pea + canola (120 + 2 kg/ha)	190.3b	-	226.9b	417.2a
Sole mustard (3 kg/ha)	-	453.3a	-	453.3a
Sole mustard (9 kg/ha)	-	392.9a	-	392.9a
Pea + mustard (120 + 3 kg/ha)	-	281.1b	192.9b	474.0a

† Values in a column followed by the same letter are not significantly different at LSD 0.05 level.
* Mean of eight plots of both nitrogen levels.

When Gisilba mustard was intercropped with Bohatyr pea its dry matter accumulation was significantly reduced (Tables 4.5 - 4.7 and Fig. 4.5a and 4.5b). The dry matter yield of mustard was reduced by 42, 35 and 38% when it was grown in association with Bohatyr pea at 26, 42, and 55 DAP, respectively. Growing Legend canola with Bohatyr pea significantly reduced the dry matter production by the former. The dry matter production by Legend canola was reduced by 53, 34, and 52% at 26, 42, and 55 DAP, respectively.

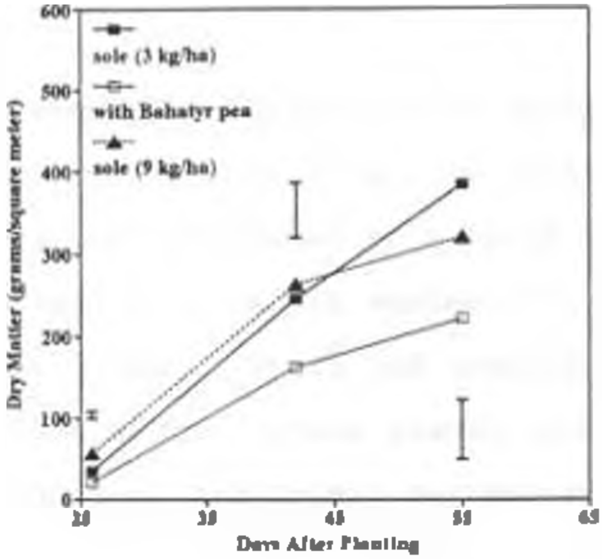

Fig. 4.5a Dry matter production by mustard in sole cropping and when intercropped with Bohatyr pea in 1991 with no nitrogen added.

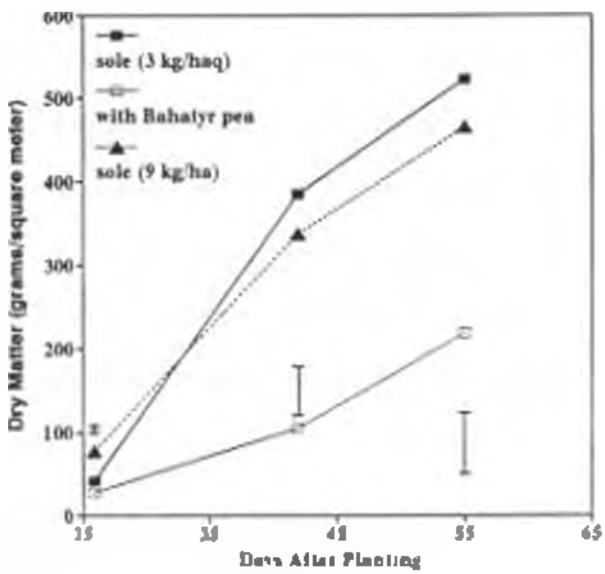

Fig. 4.5b Dry matter production by mustard in sole cropping and when intercrooped with Bohatyr pea in 1991 with 90 kg/ha of nitrogen added.

There were significant differences among the cropping system treatments in terms of total dry matter. At 26 DAP sampling date sole mustard seeded at 9 kg/ha had the highest dry matter yield and sole canola seeded at 2 kg/ha had the lowest dry matter yield. At 42 DAP pea/mustard intercrop resulted in high total dry matter yield, whereas, sole pea seeded at 120 kg/ha gave the lowest dry matter yield. At 55 DAP, there were no significant differences in total dry matter yield. However, pea/mustard intercrop still had the highest total dry matter yield.

Without the nitrogen fertilizer application the competitiveness of Legend canola and Gisilba mustard were the same until 42 DAP when Legend canola appears to have exerted more stress (Fig.4.4a). When 90 kg/ha of N fertilizer was added, Bohatyr pea as a sole crop accumulated dry matter in the same manner as Bohatyr pea intercropped with Gisilba mustard until 42 DAP. After 42 DAP Gisilba mustard appeared to have exerted competition stress on Bohatyr pea. This competition coincided with the rapid stem elongation and the flowering of the mustard.

With no N fertilizer applied the sole planted mustard seeded at 3 kg/ha and that seeded at 9 kg/ha accumulated dry matter at the same rate until 42 DAP after which the sole stand of mustard seeded at 9 kg/ha accumulated dry matter at slower rate such that it was below the sole stand seeded at 3 kg/ha at 55 DAP (Fig. 4.5a).

The addition of N fertilizer appears to have improved the dry matter accumulation rate of sole planted Gisilba mustard. The accumulation of dry matter of sole Gisilba mustard seeded at 3 kg/ha was higher than that seeded at 9 kg/ha until 42 DAP (Fig. 4.5b). After 42 DAP the dry matter accumulation of sole stands were similar until 55 DAP. However, the accumulation of dry matter by Gisilba seeded at 9 kg/ha occurred at a lower level. At 26 DAP sole mustard seeded at 9 kg/ha gave the highest dry matter yield followed by the sole mustard at 3 kg/ha. As the mustard developed, the dry matter production remained statistically similar between the two seeding rates up to 55 DAP.

The dry matter accumulation of Legend canola intercropped with Bohatyr pea with no nitrogen fertilizer applied appeared to have occurred at a low rate as compared to the sole canola seeded stands until 42 DAP after which the mean dry matter of Legend canola intercropped with Bohatyr pea remained constant (Fig.4.6a). The dry matter production by Legend canola seeded at 6 kg/ha occurred at a high rate until 42 DAP, thereafter, the accumulation rate decline such that at 55 DAP the dry matter accumulated was similar to that accumulated by sole Legend canola seeded at 2 kg/ha. T h e application of nitrogen fertilizer did not affect the competitive ability of Legend canola significantly (Table 4.8 and Fig.4.6b). However, the dry matter accumulation rate improved and the accumulation rate did not declined substantially after 42 DAP as was observed when no nitrogen was applied.

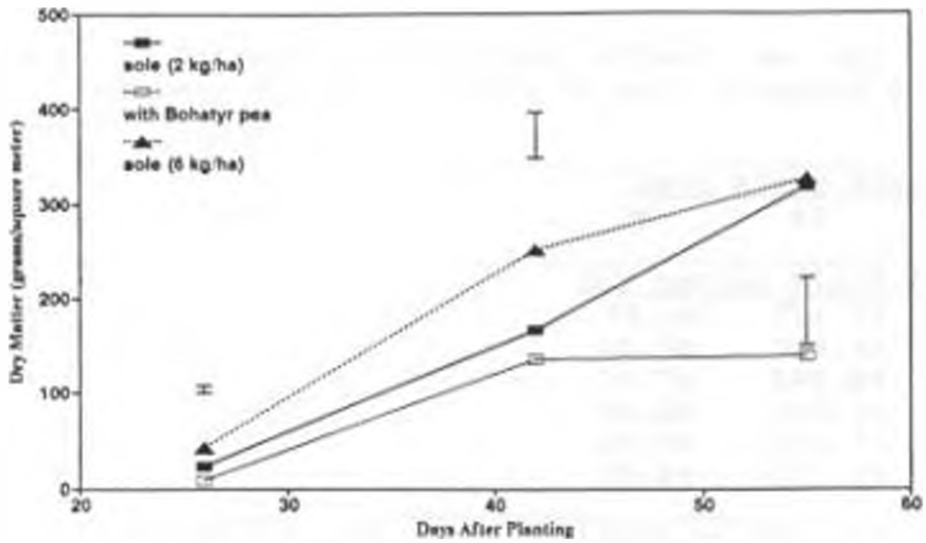

Fig 4 6a Dry matter production by Legend canola in sole cropping and when intercropped with Bohatyr pea in 1991 with no nitrogen added

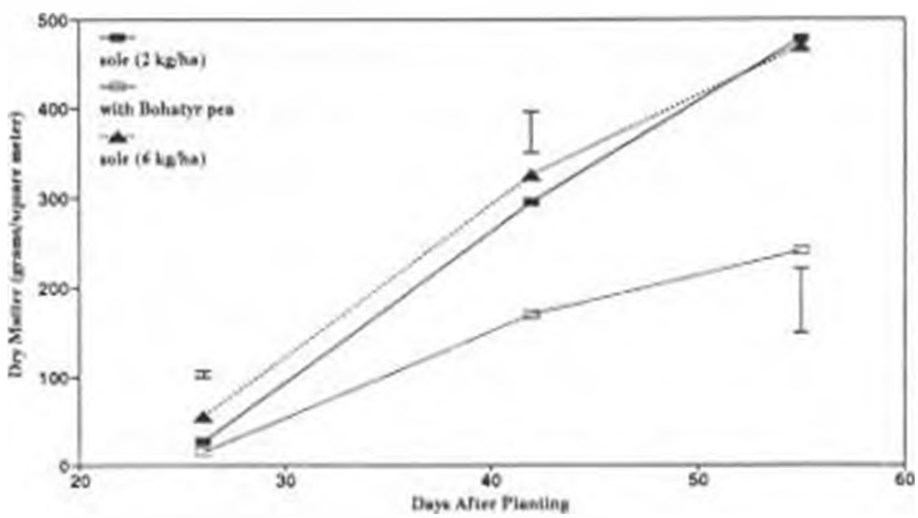

Fig 4 6b Dry matter production by Legend canola in sole cropping and when intercropped with Bohatyr pea in 1991 with 90 kg/ha of nitrogen added.

Table 4.8. Nitrogen fertilizer effect on dry matter production of pea, mustard, canola in sole cropping and when intercropped in 1991.

Crop	N level	Days After Planting		
		26	42	55
		Dry matter yield (g/m^2)		
mustard	0	37.4a[1]	224.7a	309.1a
	90	48.0a	324.4b	442.4b
Canola	0	24.7a	185.0a	262.5a
	90	40.2a	245.5a	296.3b
Pea	0	23.7a	132.8a	296.7a
	90	28.2a	195.2b	354.6a

[1] Values in column for each crop followed by the same letter are not significantly different at LSD 0.05 level.

The dry matter accumulation of sole canola sown at 2 kg/ha and that sown at 6 kg/ha occurred at the same rate until 42 DAP. The dry matter accumulation by Legend canola sown at 6 kg/ha decline after 42 DAP such that at 55 DAP it was below the dry matter production by sole planted canola at 2 kg/ha. The decline of dry matter accumulation could be attributed to intraspecific competition which set in after 42 DAP in response to the Legend plant population at 6 kg/ha seeding rate. When nitrogen fertilizer was applied the accumulation of dry matter of sole canola planted at 6 kg/ha was similar with that shown by sole canola planted at 2 kg/ha up to 55 DAP (Fig.4.6b).

In both years, canola and mustard in the intercrop did not compete well with the pea. The absence of the competitive ability by canola and mustard could be traced back to the seeding rates which were used. In the intercrop, canola and mustard contributed about one third of the plant population. Morris et al., (1990) reported that Viny, an indeterminate, late maturing cowpea cultivar depressed the yield of rice as the proportion of cowpea was increased. Maize has been shown to depress bean yield as the maize plant population was increased (Willey and Osiru, 1972).

4.3. Leaf Area Index

The cropping systems in 1990 exhibited significant differences in terms of LAI development in all the sampling dates (Table 4.9). At 32 DAP sole pea seeded at 180 kg/ha, 120 kg/ha and the intercrops of pea with canola or mustard had similar LAI. Sole mustard seeded at 3 kg/ha and sole canola seeded at 2 kg/ha gave the lowest LAI at 32 DAP. At 46 DAP the leaf area index development had changed such that canola seeded at 6 kg/ha and the sole mustard treatments had the lowest LAI. The visual observations in the field indicated that at these seeding rates senescence of the lower older leaves was apparent just before flowering. The senescence of the lower older leaves may have contributed to the observed LAI. The senescence effect appeared to have been more severe when no N fertilizer was applied. It was also apparent that when pea was intercropped with canola or mustard senescence of the older leaves occurred at a faster rate as the crops grew older.

At the first sampling date (32 DAP) there was no significant influence of the nitrogen levels on the leaf area indices (Table 4.10). At the second sampling date (39 DAP) there was a significant differences between the two levels of nitrogen. This was the time when pea was beggining to overtop mustard or canola. The shading effect may have caused more senescence in the plots which did not receive N fertilizer.At 46 DAP there was no statistical differences between the N levels. There was no differences because most of the canopy consisted of pea at this time.

Table 4.9. Leaf area indices (LAI) of sole and intercrops of pea, mustard and canola, 1990.

Treatments	Days After Planting 32	39	46
	---------LAI----------		
Sole pea (180 kg/ha)	3.1a	5.7a	5.1a[1]
Sole pea (120 kg/ha)	2.7ab	4.9b	5.2a
Sole canola (2 kg/ha)	1.5d	2.5d	4.4abc
Sole canola (6 kg/ha)	2.1c	2.5d	4.2bc
Pea + canola (120 + 2 kg/ha)	3.1a	4.9b	4.7ab
Sole mustard (3 kg/ha)	1.8cd	2.6d	4.9ab
Sole mustard (9 kg/ha)	2.2bc	2.9d	3.6c
Pea + mustard (120 + 3 kg/ha)	2.9a	4.3c	4.8ab

[1] Values followed by the same letter(s) are not significantly different at LSD 0.05 level.

Table 4.10. Nitrogen fertilizer effects on leaf area indices of sole and intercrops of pea, mustard and canola, 1990.

Nitrogen levels	Days After Planting 32	39	46
	---------LAI----------		
0	2.3a	3.5b	4.3a[1]
90	2.5a	4.0a	4.9a

[1] Values followed by the same letter(s) are not significantly different at LSD 0.05 level.

In 1991, there were significant differences in LAI among the cropping systems used in this study (Table 4.11). Intercropping generally reduces the leaf area index of the lower canopy crop and may reduce the upper canopy crop where competition for water and nutrients occurs (Zandstra, 1978). At 30 DAP sole mustard seeded at the recommended seed rate gave the highest LAI and sole pea seeded at 120 kg/ha gave the lowest LAI. The development of LAI changed such that at 52 DAP, sole pea seeded at 180 kg/ha had the highest LAI and the sole mustard seeded at 9 kg/ha the least LAI There were significant differences in LAI at all the sampling dates between those treatments which received 90 kg/ha of N fertilizer and those which did not (Table 4.12). The soil sample from the experimental area showed that it was low in inherent soil N. The low levels of soil N could be attributed to the observed differences.

Table 4.11. Leaf area indices of sole and intercrops of pea, mustard and canola, 1991.

Treatments	Days After Planting			
	30	36	44	52
	-------LAI-------			
Sole pea (180 kg/ha)	1.3ab	2.1cde	4.2a	5.4a[1]
Sole pea (120 kg/ha)	0.9b	1.8e	3.1de	4.9b
Sole canola (2 kg/ha)	1.3ab	1.9de	3.0e	3.3de
Sole canola (6 kg/ha)	1.3ab	2.6b	3.8abc	3.5d
Pea + canola(120 + 2 kg/ha)	1.5ab	2.3bcd	3.6bcd	4.6bc
Sole mustard (3 kg/ha)	1.0b	2.3bcd	3.3cde	3.2cd
Sole mustard (9 kg/ha)	1.7a	3.2a	3.4cde	3.0e
Pea + mustard (120 + 3 kg/ha)	1.2ab	2.5bc	3.9ab	4.4c

[1] Values followed by the same letter(s) are not significantly different at LSD 0.05 level.

Table 4.12. Nitrogen fertilizer effects on leaf area indices (LAI) of sole and intercrops of pea, mustard and canola, 1991.

	Days After Planting			
Nitrogen levels	30	36	44	52
	LAI			
0	1.0b	1.7b	2.5b	3.1b[1]
90	1.6a	2.9a	4.6a	4.9a

[1] Values followed by the same letter(s) are not significantly different at LSD 0.05 level.

4.4. Crop heights

Intercropping pea with mustard or canola in 1990 affected their canopy height. The canopy heights of canola and mustard were significantly shorter when intercropped than when grown in sole stands but that intercropped pea was significantly taller than those of sole planted treatments (Table 4.13).

In 1991 the first measurement of the canopy heights were taken 34 DAP. At this time of measurement canola was in the bud developmental stage (growth stage 3.1) and the mustard had just achieved 100% bloom (g.s. 4.4). The data suggest that there was no difference in the canopy height of mustard between the cropping system treatments. However, the canopy height of canola and the pea were significantly influenced by the cropping system under which they were grown (Table 4.14). When canola was seeded at 6 kg/ha the canopy height was significantly taller than when it was sole planted at 2 kg/ha

Table 4.13. Mean relative height of sole and intercrops of pea, mustard and canola measured 70 DAP, 1990.

Treatments	canola	mustard	pea
	------ Height (cm)	-----	
Sole pea (180 kg/ha)	-	-	81.9b[1]
Sole pea (120 kg/ha)	-	-	85.5ab
Sole canola (2 kg/ha)	108.9a	-	-
Sole canola (6 kg/ha)	100.9a	-	-
Pea + canola (120 + 2 kg/ha)	85.1b	-	87.9a
Sole mustard (3 kg/ha)	-	106.8a	-
Sole mustard (9 kg/ha)	-	100.1a	-
Pea + mustard (120 + 3 kg/ha)	-	89.5b	89.9a

1 Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

Similar to 1990, at 53 DAP (Table 4.15) the canopy heights of canola and mustard intercropped with pea were significantly shorter than the sole planted crop. The pea intercropped with mustard attained significantly taller canopy height than sole pea at the same seeding rate.

Table 4.14. Mean canopy heights of sole and intercrops of pea, mustard and canola measured 34 DAP, 1991.

Treatments	canola	mustard	pea
	-------Height	(cm)-------	
Sole pea (180 kg/ha)	-	-	35.5a[1]
Sole pea (120 kg/ha)	-	-	35.6a
Sole canola (2 kg/ha)	23.9b	-	-
Sole canola (6 kg/ha)	30.6a	-	-
Pea + canola (120 + 2 kg/ha)	27.5ab	-	32.5b
Sole mustard (3 kg/ha)	-	61.1a	-
Sole mustard (9 kg/ha)	-	66.9a	-
Pea + mustard (120 + 3 kg/ha)	-	61.3a	36.4a

1 Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

Table 4.15. Mean canopy heights of sole and intercrops of pea, mustard and canola measured 53 DAP, 1991.

Treatments	canola	mustard	pea
	------Height (cm)-----		
Sole pea (180 kg/ha)	-	-	90.6ab[1]
Sole pea (120 kg/ha)	-	-	86.6c
Sole canola (2 kg/ha)	99.1a	-	-
Sole canola (6 kg/ha)	98.7a	-	-
Pea + canola (120 + 2 kg/ha)	93.1b	-	87.2bc
Sole mustard (3 kg/ha)	-	95.1a	-
Sole mustard (9 kg/ha)	-	100.1a	-
Pea + mustard (120 + 3 kg/ha)	-	93.4b	90.9a

[1] Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

The shorter plant of intercropped mustard and canola could be attributed to the fact that at 70 and 53 DAP in 1990 and 1991, respectively, the pea had overtopped the canola or mustard, therefore, the pea biomass within the intercrop canopy may have caused slight bending of the canola and mustard crops. The relative height of intercropped pea was taller than when planted as a sole crop because it received physical support from the companion crop. In this study, the differences in height appears to have been a physical phenomena, however, Yunusa (1989) reported that maize plants were taller in sole stands than in mixed stands with soybean. Relative plant heights of different crops in association in an intercrop system are important. Trenbath (1974) observed that the taller crop has an advantage over its shorter crop companion even if the height difference is small. The potential share of light that will be gained by each component potential share of light that will be gained by each component in the intercrop is determined by the relative height. The taller component will intercept more light depending on the distribution and inclination of its foliage.

4.5. Grain yields

The mean grain yields of mustard, canola and pea in sole and intercropping systems are presented in Tables 4.16 and 4.17 for 1990 and 1991, respectively. The 1990 summer season intercrop yields were low. The low intercrop yields in 1990 compared to 1991 intercrop yields were realized because the experiment had to be replanted three weeks later after the first planting due the flea beetles damage which resulted in low plant population. Bird damage may have also contributed to the low yields.

Intercropping of Century pea with Gisilba mustard or with Westar canola did not affect pea yields significantly but the yields of canola were reduced by 95% and the seed yield of mustard by 87% as compared with the sole crop seeded at the same seed rate.

Table 4.16. Mean grain yields of sole and intercrops of pea, mustard and canola, 1990.

Treatments	canola	mustard	pea
	Grain yields (kg/ha)		
Sole pea (180 kg/ha)	-	-	1875a[1]
Sole pea (120 kg/ha)	-	-	1955a
Sole canola (2 kg/ha)	1891a	-	-
Sole canola (6 kg/ha)	1536a	-	-
Pea + canola (120 + 2 kg/ha)	102b	-	1947a
Sole mustard (3 kg/ha)	-	1210a	-
Sole mustard (9 kg/ha)	-	1334a	-
Pea + mustard (120 + 3 kg/ha)	-	155b	1519a

[1] Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

Table 4.17. Mean grain yields of sole and intercrops of pea, mustard and canola, 1991.

Treatments	canola	mustard	pea
	Grain yields (kg/ha)		
Sole pea (180 kg/ha)	-	-	4814a[1]
Sole pea (120 kg/ha)	-	-	4602a
Sole canola (2 kg/ha)	2225a	-	-
Sole canola (6 kg/ha)	2222a	-	-
Pea + canola (120 + 2 kg/ha)	859b	-	2703b
Sole mustard (3 kg/ha)	-	1125a	-
Sole mustard (9 kg/ha)	-	1178a	-
Pea + mustard (120 + 3 kg/ha)	-	687b	2459b

[1] Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

The intercropped pea yields was reduced by only 0.5% when it was intercropped with canola and 22% when intercropped with mustard.

The intercropping of Bohatyr pea with Legend canola in 1991 significantly affected the yields of both crops. The Legend canola yields was reduced by 61% when it was intercropped with Bohatyr pea and the pea yield was reduce by 41%. Mustard yields was reduced by 47% and that of the associated pea were reduced by 38%.

The yields of canola under sole cropping seeded at the 6 kg/ha of seed and at one third this rate did not differ statistically, as was the case with sole cropped mustard.

Table 4.18 shows the effects of nitrogen levels on the grain yields of pea, mustard and canola. Pea, mustard and canola seed yields were not significantly affected by the N fertilization levels nor was there any interaction between the N levels and the cropping system treatments in 1990.

In 1991, the nitrogen levels increased the grain yields of canola and mustard but not that of pea.

Although there was a change in the test crops in the two years, the results from this study suggest that mustard was a better competitor than canola under the intercropping situation studied. The field observations also suggest that Century pea was a more aggressive competitor than Bohatyr. Century pea is more indeterminate and its days to maturity is longer than Bohatyr pea.

Table 4.18. Nitrogen effects on grain yields of canola, mustard, and pea in sole cropping and when intercropped. grown at Portage La Prairie.

Year	N Level	Canola	Mustard	Pea
1990	0	980a	848a	1638a[1]
	90	1372a	951a	2011a
1991	0	1511a	731a	3621a
	90	2026b	1242b	3668a

[1] Values in a column followed by the same letter are not significant at LSD 0.05 level.

4.6. Thousand Seed weight

Thousand seed weight was only determined in 1991. The cropping system significantly influence a thousand seed weight of canola, mustard and pea (Table 4.19). Thousand seed weight of Bohatyr pea in sole stands both when seeded at 180 kg/ha of seed and at 120 kg/ha resulted in lower seed weight as compared to the pea seeds intercropped with canola or mustard. There were also significant differences observed with canola seeded alone and in association with the pea.

When canola was seeded at 2 kg/ha as a sole crop a thousand seed weight was lower than when it was intercropped at the same seeding rate. When it was seeded at 6 kg/ha a thousand seed weight was similar to thousand seed weight of intercropped canola. The contrary was observed with the mustard. The thousand seed weight was significantly different but in this case the intercropped mustard yielded seeds of lower thousand seed weight and the sole mustard at both the seed rates used resulted in seeds of higher thousand seed weight.

Table 4.19. Thousand seed weight of pea, mustard and canola planted in sole stands and when intercropped, 1991.

Treatments	Canola	Mustard	Pea
	Thousand seed weight (g)		
Sole pea (180 kg/ha)	-	-	244a[1]
Sole pea (120 kg/ha)	-	-	247a
Sole canola (2 kg/ha)	4.2a	-	-
Sole canola (6 kg/ha)	4.5b	-	-
Pea + canola (120 + 2 kg/ha)	4.5b	-	262b
Sole mustard (3 kg/ha)	-	6.0a	-
Sole mustard (9 kg/ha)	-	6.1a	-
Pea + mustard (120 + 3 kg/ha)	-	5.7b	268b

[1] Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

The above mentioned observations could be explained in terms of crop characteristics and the ability to compete. Pea under the intercropping situation studied, probably experienced competition stress at the time of important vegetative and reproductive stages and so resulted in development of fewer pods and so the photosynthate source had to supply fewer developing seeds as compared to sole cropped pea. The same story applies to canola but with canola seeded at 6 kg/ha, intra-specific competition which occurred during its growth and development resulted in the higher seed weight. McGregor (1987) found that plant density was significantly correlated with seed weight in canola. The reduction in plant population results in increased branching and hence many pods which compete for photosynthate. The mustard thousand seed weight difference occurred due to the fact that it flowered at the time when the pea had not exerted any competition stress and so fewer flowers aborted. But pea in combination with mustard may have competed with mustard after flowering and this therefore, resulted in the significantly lower thousand seed weight of mustard in that the source of photosynthate could supply many developing seeds.

These observations imply that depending on the time the stressful situation occurs the seed weight is either reduced or increased. If the stress occurs before anthesis few flowers will result and this may lead to larger seeds whereas if it occur after anthesis lower seed weight might be realized. Similar observation were made by Kiniry working with sorghum (1988).

4.7. Land Equivalent Ratio

Yield advantages in an intercropped situation can be measured by Land Equivalent Ratio (LER). The calculation of LER from grain yields in 1990 indicated that there was no advantage in intercropping pea with canola or mustard but the calculation from dry matter gave LER greater than unity and significant (Table 4.20). Application of N fertilizer did not affect LER in 1990. In 1991, intercropping of mustard or canola with pea increased the LER (Table 4.21). LER indicated that more land would have been needed if the crops were planted separately in order to obtain the same dry matter and grain yields.

The application of N fertilizer decreased LER. Some authors have reported decrease in LER with increase in N rate (Cowell et al, 1989; Ahmed and Rao, 1982)

Table 4.20. Land Equivalent Ratios derived from grain yields and dry matter yields of canola, mustard and pea in sole cropping and when intercropped, 1990.

Treatments	LER1[1]	LER2	LER3	LER4
	Land Equivalent Ratio			
Sole pea (180 kg/ha)	1.00	1.00	1.00	1.00
Sole pea (120 kg/ha)	1.00	1.00	1.00	1.00
Sole canola (2 kg/ha)	1.00	1.00	1.00	1.00
Sole canola (6 kg/ha)	1.00	1.00	1.00	1.00
Pea + canola (120 + 2 kg/ha)	1.12	1.29	1.61	1.55
Sole mustard (3 kg/ha)	1.00	1.00	1.00	1.00
Sole mustard (9 kg/ha)	1.00	1.00	1.00	1.00
Pea + mustard (120 + 3 kg/ha)	0.90	1.21	1.34	1.14

1 LER1, LER2, and LER3 refer to Land Equivalent ratio calculated from grain yields, dry matter harvested 29, 43, and 64 days after planting, respectively.

Table 4.21. Land Equivalent Ratios derived from grain yields and dry matter yields of canola, mustard and pea in sole cropping and when intercropped, 1991.

Treatments	LER1[1]	LER2	LER3	LER4
	Land Equivalent Ratio			
Sole pea (180 kg/ha)	1.00	1.00	1.00	1.00
Sole pea (120 kg/ha)	1.00	1.00	1.00	1.00
Sole canola (2 kg/ha)	1.00	1.00	1.00	1.00
Sole canola (6 kg/ha)	1.00	1.00	1.00	1.00
Pea + canola (120 + 2 kg/ha)	1.02	1.34	1.31	0.99
Sole mustard (3 kg/ha)	1.00	1.00	1.00	1.00
Sole mustard (9 kg/ha)	1.00	1.00	1.00	1.00
Pea + mustard (120 + 3 kg/ha)	1.15	1.51	1.25	1.09

1 LER1, LER2, and LER3 refer to Land Equivalent ratio calculated from grain yields, dry matter harvested 26, 42, and 55 days after planting, respectively.

4.8 Economic Analysis

As it was indicated elsewhere, the 1990 experiment was planted three weeks later and could have contributed to the observed low yields. The low yield in 1990 reflects the low net returns as compared to the net returns obtained in 1991 (Table 4.22). The net returns derived from the 1990 yields appears to suggest that it was more economical to grow canola in sole stands. There was no significant differences between the sole canola seeded at 6 kg/ha and that seeded at 2 kg/ha. In fact, there were no differences between the two seeding rates of sole stands of the pea, mustard, and canola in this study. The net returns realized from intercropping was significantly lower than when the crops seeded were as sole crops.

The 1991, net return results indicate that the growing of pea in sole stands was more profitable. The net returns of sole planted canola crop was similar to the net returns realized from intercropping. Mustard in sole stands resulted in significantly low net returns.

The net returns in both years suggest that there was no advantage of intercropping pea with canola or mustard if the major objective was to achieve higher net returns. However, if the aim of the farmer is to improve the combining operation of the pea and to reduce the loss in pea seed quality then intercropping would be appropriate.

Table 4.22. Net returns obtained from sole cropping and intercropping pea with canola or mustard in 1990 and 1991.

Treatments	Net returns($)/ha 1990	1991
Sole pea (180 kg/ha)	31cd	546a[1]
Sole pea (120 kg/ha)	33cd	526a
Sole canola (2 kg/ha)	216ab	443b
Sole canola (6 kg/ha)	316a	426b
Pea + canola (120 + 2 kg/ha)	44cd	376b
Sole mustard (3 kg/ha)	150b	102c
Sole mustard (9 kg/ha)	114bc	86d
Pea + mustard (120 + 3 kg/ha)	-27d	346b

[1] Values in a column followed by the same letter are not significantly different at LSD 0.05 level.

4.9. Lodging

There were significant lodging differences among the treatments in both years of this study (Table 4.23). Pea plants lodged completely at both seed rates used. Intercropping pea with mustard or canola reduced the lodging of pea dramatically. However, intercropping caused mustard and canola to lodge noticeably. Sole stands of mustard and canola did not lodge. It was more difficult to straight combine sole pea than it was when it was intercropped with mustard or canola. With sole pea, the pick up system of the plot combine had to be fitted with pickup fingers and in most instances it had to be placed very low in order to pick up the pea. The combine had to be run over the plot more than one time.

Table 4.23. Lodging scores of sole and intercrops of pea, yellow mustard and canola, 1990 and 1991.

Treatments	Lodging scores*	
	1990	1991
Sole pea (180 kg/ha)	4.8a	4.7a[†]
Sole pea (120 kg/ha)	4.6a	4.8a
Sole canola (2 kg/ha)	1.0c	2.3c
Sole canola (6 kg/ha)	1.0c	2.3c
Pea + canola (120 + 2 kg/ha)	3.6b	3.8b
Sole mustard (3 kg/ha)	1.0c	1.3e
Sole mustard (9 kg/ha)	1.0c	1.4e
Pea + mustard (120 + 3 kg/ha)	3.6b	2.8c

[†] Values in a column followed by the same letter(s) are not significantly different at LSD 0.05 level.

* Scores used in this case was a scale of 1 to 5; where 1 represented no lodging and 5 completely lodged.

4.10. Correlation.

The relationship between yield and other parameters measured, and among the parameters was determined. In 1990, there was a positive and significant correlation between yield and the leaf area index measured 39 DAP (Table 4.24). There was also a positive and significant correlation between LAI2 and LAI3, and TDM3.

In 1991, there was a positive and significant correlation between yield and LAI2, LAI3, and TDM1 (Table 4.25). There were positive and significant correlations between LAI2 and all the other parameters measured. LAI1 had positive and significant correlation with other parameters except total yield.

Table 4.24. Correlation between total yields, leaf area indices, and total dry matter of pea, mustard and canola grown at Portage la Prairie in 1990.

	LAI1[1]	LAI2	LAI3	TDM1	TDM2	TDM3	TYLD
LAI1	-	0.781**	0.267*	0.463**	0.32**	-0.206	0.211
LAI2		-	0.263*	0.481**	0.107	-0.266*	0.392**
LAI3			-	0.177	0.035	0.07	0.213
TDM1				-	0.284*	-0.174	0.140
TDM2					-	0.05	0.048
TDM3						-	0.145

1 LAI1, LAI2, LAI3, represent leaf area indices measured 32, 39, and 46 days after planting, respectively; TDM1, TDM2, and TDM3 represent total dry matter harvested 29, 43, and 64 days after planting, respectively; TYLD represent total intercrop yields.
*, ** Significant at LSD 0.05 and 1% respectively.

Table 4.25. Correlation between total yields, leaf area indices, and total dry matter of pea, mustard and canola grown at Portage la Prairie in 1991.

	LAI1[1]	LAI2	LAI3	TDM1	TDM2	TDM3	TYLD
LAI1	-	0.700**	0.384**	0.504**	0.503**	0.389**	-0.211
LAI2		-	0.744**	0.268*	0.454**	0.472**	0.222**
LAI3			-	-0.069	-0.175	0.453**	0.66**
TDM1				-	0.463**	0.076	0.343**
TDM2					-	0.288**	-0.187
TDM3						-	0.183

1 LAI1, LAI2, LAI3, represent leaf area indices measured 36, 44 and 52 days after planting, respectively; TDM1, TDM2, and TDM3 represent total dry matter harvested 26, 42, and 55 days after planting,respectively; TYLD represent total intercrop yields.
*, ** Significant at LSD 0.05 and 0.01 respectively.

In both years the parameters that were measured consecutively had significant correlations. It also appears that leaf area indices measured between 39 and 44 DAP correlated well with the other parameters. Shaw and Weber (1967) indicated that yield was positively correlated with the amount of leaf area in soybean study.

5.0. GENERAL DISCUSSION

Intercropping as a farming practice could offer yield advantages as compared to sole cropping in form of higher yields, better dollar returns, better sustainability of land, more stable and less risk in terms of output over the years. The yield advantages could be viewed from different angles depending on the farmers objectives, the region, and the environmental conditions under which intercropping is practised.

From the point of view of a subsistence farmer, intercropping is more meaningful because it can better satisfy the families dietary needs. In a subsistence farming situation farm labour is not usually a constraint and in such a case labour is effectively utilized under an intercropping system. This study would not fit a subsistence farmers situation in that the mustard and canola intercrops would not be used by the farmer directly before undergoing industrial processing although it can earn some cash for the farmer. In regions where subsistence farming is abundantly practised, markets and marketing outlets are generally lacking. Also, much more losses would be incurred due to the shattering losses during harvesting and threshing process. It would, however be appropriate to a commercial farmer whose aim is to improve the harvesting operation of pea. Lodging is the biggest problem that affect direct combining of field pea and may result in yield losses. Murphy (1981) reported that losses incurred due to staining and shedding of pea seeds is of significance. From this study, it was apparent that both mustard and canola provided some support to the pea. The support provided was enough to facilitate straight combining of the pea. It should be borne in mind, however, that the crops chosen for intercropping mature at approximately the same time. If one matures early, then there would be losses in terms of seed shattering or the quality would deteriorate due to field weathering.

On the other hand, it is most likely that the crops that mature at the same time have the same phenological growth pattern such that the most important vegetative and reproductive stages coincide. When and if this happens, then they would compete for the growth resources severely and this would lead to reduced growth and development and consequently reduced productivity. This implies that the genotypes chosen for intercropping differ in their growth patterns and that their critical growth factor requirements differ in time.

From this study, it was noted that pea was a dominant component in the intercrop. Since the major aim in western Canada is to improve the harvesting operation of field pea, this would be perfectly acceptable. The dominance of pea differed in the two years of this study. The observed difference could be attributed to the change of the cultivar of pea. The change was necessitated due to the differences in the time of maturity between 'Century' pea and canola or mustard observed in 1990. Mustard and canola matured one week earlier. The big differences in time of maturity is undesirable because this would lead to much losses due to shattering of the minor component especially the canola. The change to a new pea cultivar in 1991 worked well as far as the time of maturity was concerned but there was a sacrifice in terms of poor competitive ability of 'Bohatyr' pea with its components.

Intercropping did not appear to have affected the growth and development of pea, canola, and mustard in this study. Robinson (1984) observed that intercrop competition with sunflower was injurious to corn and soybean but not to mustard. Sunflower and mustard differ greatly in time of major vegetative and reproductive growth. Variation in cropping systems can profoundly influence the development of a crop variety. Makena and Doto (1980) showed that intercropping hastened soybean flowering and maturity. However, Natarajan and Willey (1979) reported that the onset of pigeonpea flowering was delayed when it was intercropped with sorghum. In the present study, the onset of flowering of pea, canola, or mustard were not affected by the cropping system.

The results of the field study indicated that the dry matter yield of 'Century' pea was not significantly influenced by intercropping with mustard or with canola in 1990. This was not the case in 1991. The dry matter production of

'Bohatyr' pea was significantly reduced by intercropping with mustard or canola. Field visual observations indicated that 'Century' pea was more aggressive than 'Bohatyr'. Liebmann (1989) reported that final biomass of mustard was lower when it grew with 'Century' pea than when it grew with 'Alaska' pea. He also observed that mustard was overtopped and severely shaded and was not the case when mustard grew with 'Alaska' pea.

In this study, the application of N fertilizer did not influence the dry matter accumulation and grain yield of pea in both years. This is consistent with what have been reported in the literature (Cowell et al., 1989; Izaurralde et al., 1990; Liebman, 1989; Tomar et al., 1988; Vessey et al., 1992). With regard to grain yields, the pea yields obtained in 1990, were less than that was obtained in 1991. Although the yields were low in 1990, it was apparent that the yields of 'Century' pea was not significantly affected by intercropping. The yields of 'Bohatyr' pea was significantly reduced.

It could be argued that the observed reduction of yield of 'Bohatyr' pea when intercropped could be due to the year effect. The year effect factor is dismissed by the fact that 1991 was a better year in terms of weather conditions and that the 1990 experiment was seeded late. In this study there was no yield advantage of intercropping in terms of net returns. Similar work done by Stobbe (personal communication) between

1987 and 1989 indicated that it was economical to intercrop pea with mustard or canola. It was not economical to intercrop pea with canola or mustard in this study apparently because of two major reasons. Firstly, due to poor yields obtained in 1990 because of late planting of the experiment and secondly, due to planting of incompatible component crops in 1991. The yield advantage was not realized because the components maturity time only differed slightly. The small difference in time of maturity could have resulted in competition between the component crops for growth limiting factors. It has been shown that intercropping component crops with contrasting maturities result in yield advantages. Natarajan and Willey (1980) obtained a 62% yield advantage with 82 day sorghum and 173 day pigeonpea. In contrast, no yield advantages were obtained in the sorghum-cowpea intercrop system in which the component crops were of similar growth durations (Andrews, 1972; Rees, 1986).

The difference in response by varieties to cropping systems may influence the seed weight. It was shown by Makena and Doto (1980) that seed weight of soybean varieties were affected differently depending on the cropping system under which they were grown. Elmore and Jackobs (1984) found out that seed weight of a soybean variety was greater in intercrop than in sole cropping.

The determination of land equivalent ratio from the dry matter and the grain yield indicated values greater than unity. The implication of this observation is that more land would have been required for sole crops in order to achieve the same amount of dry matter and grain yields as intercrops. From this point of view, the intercropping was beneficial. In this study, the LER determined from grain yield would be a better indicator of the beneficial effect of intercropping. The LER determined from dry matter would be a better indicator if the crops were intended for forage production. Several authors think that LER determinations puts the intercrops in a better situation for comparison (Willey,1979; Mead and Willey, 1980; Chetty and Reddy, 1984.). The component crops usually differ in the characteristics of their yield components and, therefore, makes the comparison difficult because the differences are already present.

In this study the LAI of the individual component crops making up the intercrop situation was not measured simply because the equipment used can not distinguish between the component crops. Two species growing together form a canopy that intercepts light quantitatively and qualitatively differently than either of the sole crops (Vandermeer,1989). The LAI measurements indicated that the intercrops LAI was intermediate between those of the sole component crops.

The LAI measured 6 weeks after planting had positive and significant correlation with the intercrop total grain yields. The implication of this observation is that with higher LAI, higher intercrop yields are realized. Since there was no partitioning of LAI to those of component crops, and due to the technical limitation associated with light measurements within the intercrop canopy, it is not possible to conclude that the intercrops had better light interception and utilization than sole crops in this study.

Crop production which involves high utilization of N fertilizer might result in environmental pollution. Intercropping with legumes might reduce fertilizer N requirements while improving the soil quality.

6.0. SUMMARY AND CONCLUSION

Although two different pea cultivars were used in the two years of this study to intercrop with canola or mustard, it was apparent that pea was the dominant component in the intercrop. There seemed, though, that pea cultivar differences exist in their competitive abilities.

Between the non-legumes used mustard was a better competitor canola. The competitiveness of mustard is related to its fast phenological development relative to that of the intercrop pea component.

Intercropping pea with canola or mustard resulted in improved harvest operation compared to sole planted pea. The harvesting operation was improved because intercropping reduced pea lodging significantly and it

Intercropping increased the land equivalent ratios in both years but the economic analysis indicated that intercropping was not better than sole planted stands.

Intercropping either increased or reduced thousand seed weight of the intercrops depending on the cultivar response to the cropping system and the competition from the component crop.

Nitrogen fertilization had no effect on pea yields in both years but improved the yields of the non-legumes in 1991.

Intercropping involves competition, and as such can be viewed as a type of stress. Breeding programmes usually incorporate tolerance to stress. Cultivars that can tolerate competition stress are more suitable for intercropping. Cultivar selection should, therefore, be directed at minimizing intercrop competition and maximizing complementary effects.

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Table A1. Long term average and growing season monthly temperature and precipitation at Portage La Prairie in 1990 and 1991.

Month	Year	Temperature (°C)			Precipitation
		Maximum	Minimum	Mean	Total (mm)
May	Normal	17.6	4.7	11.2	11.2
	1990	17.5	2.8	10.2	42.7
	1991	19.8	8.3	14.1	64.3
June	Normal	23.1	10.8	17.0	75.7
	1990	24.4	11.5	18.0	133.6
	1991	24.6	12.7	18.7	89.3
July	Normal	25.9	13.5	19.5	76.3
	1990	25.4	13.0	19.2	53.6
	1991	25.3	13.9	19.6	85.2
August	Normal	24.7	12.0	18.4	80.0
	1990	26.8	13.0	19.9	42.6
	1991	27.7	13.1	20.4	11.2

Table A2. Soil analysis from experimental area.

Year	Depth (cm)	pH	Available nutrients (kg/ha)			
			NO_3-N[1]	P[2]	K[3]	SO_4-S[4]
1990	0-15	7.7	24.8	18.9	557	42+
	15-60	7.7	137.3			126+
1991	0-15	7.6	5.8	13.7	509	36+
	15-60	7.7	7.8			36+

[1] Sodium bicarbonate extractable
[2] Sodium bicarbonate extractable
[3] Ammonium acetate exchangeable
[4] Water soluble sulphur