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COMPETITION and BENEFICIAL EFFECTS
in an INTERCROP of
CORN and BEANS

by

RALPH C. MARTIN, B.A.

A thesis submitted to the Faculty of Graduate
Studies and Research in partial fulfilment
of the requirements for the degree of
Master of Science

Department of Biology

Carleton University

Ottawa, Ontario

March 1985

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"COMPETITION and BENEFICIAL EFFECTS
in an INTERCROP of
CORN and BEANS"

submitted by Ralph C. Martin, B.A.
in partial fulfilment of the requirements for
the degree of Master of Science

Thesis Supervisor

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To the memory of my friend, Edward James Phelan
(April 15, 1894 - March 28, 1985). "When there
was a good turn to be done, Eddie turned it."

Abstract

Four cropping systems, corn (C), beans (B) intercropping simultaneously (Is), and intercropping with bean planting delayed (Id) were studied in conjunction with three nitrogen fertilizer levels, 0, 60 and 120 kg N/ha. The biomass and total nitrogen of each component crop was greater with monocropping than with intercropping. The percentage nitrogen of each component crop was not significantly different between cropping systems and therefore nitrogen transfer from beans to corn was not indicated. The weight of total silage was highest in C, lower in Id and Is and least in B. The total nitrogen of total silage was generally not significantly different between cropping systems. The percentage nitrogen of total silage was highest in B, lower in Id and Is and lowest in C. Is-60 N as a high-quality silage was significantly greater than C-120 N in percentage nitrogen. Land Equivalent Ratios were most advantageous in Is-60 N with Id-120 N and Id-60 N showing somewhat less advantage. C-120 N was slightly more cost effective than Id-120 N and Is-60 N.

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List of Abbreviations

B	Beans monocropped
BSe	Bean seeds
C	Corn monocropped
CS	Cropping systems
DF	Degrees of freedom
FL	Fertilizer levels
ha	hectare
Id	Intercropping delayed
Is	Intercropping simultaneously
kg	kilograms
LER	Land Equivalent Ratio
MS	Mean Square
PNBR	Percentage nitrogen of bean roots
PNBSe	Percentage nitrogen of bean seeds
PNBsil	Percentage nitrogen of bean silage
PNCK	Percentage nitrogen of corn kernels
PNCsil	Percentage nitrogen of corn silage
PNCSt	Percentage nitrogen of corn stalks
PNTsil	Percentage nitrogen of total silage
ppm	parts per million
rep	replication
sil	silage
SS	Sum of squares
TMNS	Total mineralized nitrogen of soil
TN	Total nitrogen
TNBR	Total nitrogen of bean roots
TNBsil	Total nitrogen of bean silage
TNCK	Total nitrogen of corn kernels
TNCsil	Total nitrogen of corn silage
TNTsil	Total nitrogen of total silage
WBSil	Weight of bean silage
WCR	Weight of corn roots
WCsil	Weight of corn silage
WTsil	Weight of total silage
YR	Yield Ratio
0 N	0 kg of N fertilizer per ha
60 N	60 kg of N fertilizer per ha
120 N	120 kg of N fertilizer per ha

"Since human beings have not yet advanced to the point of evolving a totally new and well-adjusted ecosystem they have to follow closely on nature's heels. This is precisely what mixed cropping does. Although it is not a perfect replication of nature, its environmental rationale is infinitely superior to that of monoculture."

(Igbozurike, 1971)

Introduction

Food surpluses have been common in developed countries, for several decades, due to advances in plant breeding and maximum use of fertilization and mechanization. The climate of the last several decades has also been unusually ideal for agricultural production in latitudes affected by predominantly westerly winds (Bryson and Murray, 1977; Ladurie, 1971). Recent recognition of the limitations of modern agriculture has been documented by Sparrow (1984), who noted that our preoccupation with increased productivity, monoculture and large, heavy machinery has contributed to the loss of organic matter, soil compaction and erosion. The maximum economic utility of a given plant species in a monocrop has eclipsed the concept of plants as interwoven threads in an ecosystem of soils, water, air, other vegetation, animal life and variable climatic conditions.

Intercropping has frequently been shown to be an advantageous cropping system in the context of sustainable agriculture and immediate crop production goals. It has been well established that the Land Equivalent Ratio (LER; the relative land area under sole crops that is required to produce the yields achieved in intercropping) is frequently advantageous for an

intercrop (Faris et al., 1983; Francis et al., 1982b, 1982c; Willey 1979a; Sanchez, 1976 and others).

Exceptionally high LER values of 2.04 to 2.69 were reported by Remison (1978) with intercropped corn and cowpeas, although any value greater than 1.00 represents an intercropping advantage. Sometimes the yield of one crop is considered to be too important to risk its reduction by competition in an intercrop even if the other component crop yields well enough to show an advantageous LER value for the intercrop. However, intercropping does not necessarily decrease the yield of a valuable crop (Knapp, 1982; Willey and Mead, 1980; Willey, 1979a).

The cited explanations of overyielding by intercrops are the conditions of temporal complementarity (Baker, 1974) and spatial complementarity (Trenbath, 1974). Frequently one crop is planted later than another and intercropping may cause deeper root growth, as a result of competition, for greater penetration of soil volume. A greater Leaf Area Index (LAI) with more efficient light interception may also occur in an intercrop (Trenbath, 1974).

Soil degradation and soil erosion may also be limited by intercropping (Knapp, 1982). Fast growing ground cover crops planted with cash crops can protect soil from excessive rain drop impact. The increased

vegetation of intercrops can also reduce the extent of runoff on slopes (El-Swaify and Dangler, 1982; Lal, 1982).

Stability in agricultural production is preferable for predictable supplies to sophisticated markets or a subsistence farming family. Pearce and Edmondson (1984, 1982) and Norman (1971), explained that many small farmers reduce the risk of crop failure by intercropping, to ensure at least one harvestable crop or to enhance the possibility of at least minimum yields of two necessary crops. Schultz (1983), addressed the problem of annual variation in crop production and suggested that spatial variation with combinations of intercrops and sole crops may be the best buffer. He noted that competing component crops of an intercrop may enhance crop failure in a season of unfavourable conditions, such as a drought.

Intercropping has also been effective in the reduction of pests and diseases. With a mixture of corn and beans, van Rheen et al. (1980) demonstrated a lower incidence of halo blight, bean common mosaic, anthracnose, common blight, scab, phoma, mildew, bollworm and angular leaf spot although the opposite effect occurred with white mold and black Systates. In an intercrop of corn, beans and squash significantly lower numbers of both specialist and generalist beetles

were found on their host plants (beans and squash). This was attributed to different overall patterns of beetle movements in intercrops as compared to pure stands (Risch and Hansen, 1982). During the summer of 1984 the proportion of corn stalks infected by the European Corn Borer was significantly decreased by intercropping with clover in field trials near Ottawa (Martin et al., 1985).

In addition to the tradition of intercropping in Latin America, Lipman (1912) stated that the favourable influence of legumes grown in association with non-legumes has long been recognized and incorporated into cropping systems by farmers in China, Japan, West Asia, North Africa, and ancient Rome. He concluded that a non-legume could secure nitrogen from an associated legume but this was subject to conditions such as moisture availability, planting density, legume inoculation and available soil nitrogen. Thornton and Nicol (1934), also reported that nitrogen appeared to be excreted from lucerne and taken up by grass in mixtures of these species. A few years later at Rothamsted, Nowotnowna (1937) observed that rye grass increased in weight and uptake of total nitrogen when grown with legumes. In his lab in Finland, Virtanen demonstrated a similar phenomenon but his results could not be replicated in the U.S.A. by Wilson. Later, in

the 1940's Virtanen was unable to repeat his own results and could not explain the discrepancies (Virtanen and Miettinen, 1963; Wilson and Wyss, 1937). More recently, evidence of nitrogen transfer from legumes intercropped with non-legumes has been noted by Vallis (1983), Eaglesham et al. (1981), Haystead and Marriott (1979), and Agboola and Fayemi (1972).

A potential practical advantage of intercropping corn with a legume such as pole beans is that nitrogen fertilizer costs may be reduced since beans can fix atmospheric nitrogen. In addition, supplemental protein costs of dairy and beef farmers may be reduced with the inclusion of high-protein bean seeds in the silage.

The component crops of corn and pole beans were carefully selected for this study. A legume and non-legume were chosen to provide an opportunity to look for possible nitrogen transfer. Corn is very palatable with its high rate of total digestible nutrients and net energy and is easily ensiled to be fed to dairy and beef cattle (Morrison, 1956). Corn is an important crop in the Region of Ottawa-Carleton in Eastern Ontario. In 1983, 30,000 acres of grain corn and 22,000 acres of silage corn were grown in the county with a total economic value of \$14,282,000 (OMAF, 1984). Pole beans were chosen as the companion legume of corn because: pole beans were found to enrich

soil with nitrogen more than soybeans (Ruschel et al., 1979); corn and pole beans have been grown traditionally in Latin America as well as North America for centuries (Fanjul et al., 1982; Francis, 1978); pole beans can easily be harvested as silage with corn by the use of current machinery because they are tightly entwined around the corn stalks (pers. observ., 1982); pole beans were not expected to be adversely affected by the shading of corn leaves (Fanjul et al., 1982; Francis et al., 1978b); and Francis et al. (1982a, 1982b) and Bryan and Materu (1981) experienced some success with corn and pole beans.

The experiment was designed to provide more information about the phenomena of competition and complementarity and the dynamic balance of their inverse relationships. If a given experimental intercropping treatment had a greater response to a factor than a second treatment the difference between the treatments could be said to be positive. One could then say that competition increased from the first to the second treatment while complementarity decreased, with respect to the measured variable. The response variable or indicator might be the LER but it could well be a measurement of weight or nitrogen of a component crop in the mixture which is perceived to be critical in the overall success of the intercrop. A

deliberate attempt has been made to compare several variables in addition to LER values. To gain an overview of the results one can then qualitatively compare increases and/or decreases in competition and/or complementarity, between treatments.

While the factor of most interest is the cropping system factor, the influence of the factor of fertilizer levels and the interaction of these two factors is also explored. For this reason a split-plot design was used and subsequent tests of differences between treatments were analyzed on this basis. LER values and cost effectiveness values were not statistically tested however, but used as comparative indices.

The general objective of the study is to distinguish differences between the monocrops of corn and beans and two intercropping systems of these species, to assess the relative merits of intercropping. The experiment was specifically designed to address the following questions;

- 1) How do the factors of cropping systems and nitrogen fertilizer levels affect the response of biomass and nitrogen in corn and/or bean plants?
- 2) Does circumstantial evidence exist to indicate that nitrogen can be transferred from beans to corn?
- 3) Are the LER values increased or decreased by an

intercrop of corn and beans?

4) What is the relative cost effectiveness of treatments of monocropped and intercropped corn?

Materials and Methods

Experimental Procedure

The methods employed for this research were on a small scale but were intentionally developed for possible application in regular agricultural practice.

The plowed study site was cultivated three times and harrowed before the hand sprayer application of 2.75 l/ha of the herbicide, Dual. The study site was then divided into 48 plots of six rows each. Corn and beans were planted by hand on May 21, 1983 according to treatment requirements. The beans in the intercropped simultaneously (Is) treatments were planted within the rows of corn and on the same day. The intercropped delayed (Id) treatments had beans planted on June 4, two weeks later, within the corn rows as well.

Fertilizer was incorporated in shallow trenches beside the seeds, to simulate a corn planter, at the rate of 30 kg/ha of phosphorous and 20 kg/ha of potassium. Nitrogen fertilizer was similarly applied, as urea, at the rates of 0, 60 or 120 kg actual N per hectare.

The six rows of pole beans were provided with strings to climb in the monocropped bean treatments. This is a level of management which was necessarily more complicated than with intercropped beans and was included for comparative purposes rather than as a

feasible farming method.

Pioneer 3859 corn hybrid (Zea mays L.) was planted at the rate of 60,000 seeds/ha or one seed per 18.5 cm of row, whether as a monocrop or an intercrop (Bryan, 1981; Francis et al., 1978a, 1978b). The Kentucky Wonder pole beans (Phaseolus vulgaris L.) were planted at the rate of 100,000 seeds/ha, or one seed per 11 cm of row in each cropping system (Francis et al., 1978b). After three weeks all non-germinated corn and bean seeds were replaced. Because of the cool wet weather in May (Table 1), the germinated seeds had barely emerged from the ground. The rows were all 6 m long and 90 cm apart, with 6 rows in each plot.

The sampling of plants and soil was completed between September 20-26. In line with the recommendations of Davis et al. (1981), the central 4 metres of the inner 4 rows of plants were harvested. All the plant parts were separated and weighed to obtain the total fresh weight of each plant part per plot. The corn was divided into stalks, leaves, tassles, cobs and husks and beans were divided into stems, leaves and pods. The kernel weight was based on the shelling percentage of kernels / (kernels + cob) on the basis of two cobs from each plot selected from among the total harvested cobs. In a similar manner the shelling percentage of bean seeds was calculated from approximately 20 pods per plot. Although there

Table 1

Climatic Data

	May	June	July	Aug.	Sept.
Precipitation(mm) 1983	130.9	52.8	64.3	30.6	58.4
45 yr. average	67.9	73.4	85.9	88.4	79.3
Temperature(°C) 1983	10.6	19.4	21.4	21.1	17.1
45 yr. average	12.8	18.0	20.6	19.2	14.3

(Environment Canada, 1983)

was a possible bias because well-developed fully-kernelled cobs were selected it was considered to be the same bias for each plot. This is a common method for sampling corn in field plots when the total yield of cobs with kernels is weighed immediately and a subsample is needed for drying. (R. Hamilton, Agriculture Canada, pers. comm.) To reduce labour, six corn roots and twelve bean roots were removed from each plot rather than sampling all roots of the harvested plants. Each root was frozen and later washed and weighed for fresh weight. Each plant part was subsampled from each plot, dried in an oven at 60°C for three days and then weighed to determine dry weights. These dry samples were then finely ground in a Wiley Mill (20 mesh) for Kjeldhal analysis.

A pooled soil sample of the study site was taken before planting in May. Soil cores, taken from each row between adjacent plants, were pooled for each plot in September. In the intercropped plots the soil cores were always taken between a corn plant and a bean plant. The soil was oven dried for three days at 60°C and then sieved through a 1 mm sieve in preparation for nitrogen analysis. All plant samples were analyzed for percentage nitrogen with an automatic Kjel-Foss machine which determines the Total Kjeldhal Nitrogen (TKN). This includes organic and inorganic ammoniacal nitrogen, but not nitrate or nitrite (George Morris,

Agriculture Canada, pers. comm.). An extraction process with 2N KCl to extract inorganic ammonia and nitrate was used before analysis with an N autoanalyzer (Sheldrick, 1984) on all soil samples. For soil and plant samples, every fifth sample was analyzed twice to ensure a consistent standard of analysis.

Description of the Study Site

The study site was located in a field beside the Smith Falls-North Gower highway about 1.5 km west of North Gower. It was on level, stone-free, tile-drained, North Gower Clay Loam (Hills et al., 1944). The A horizon of silty clay was dark brown, well-granulated and extended to a depth of at least 20 cm.

The previous crops in 1980, 1981 and 1982 were spring wheat, corn and corn, respectively. In both the springs of 1981 and 1982, 120 kg/ha of 7-27-12 fertilizer was applied in addition to 100 kg/ha of urea (46-0-0). During both the falls of 1981 and 1982, 250 kg/ha of 5-20-10 fertilizer was broadcast on the field.

The plots were arranged as shown in Figure 1. Each plot was 6 m x 5.4 m with 6 rows/plot 90 cm apart. The rows ran perpendicular to the highway in a northwest-southeast orientation. The path between each module of fertilizer levels was at least 1 m.

Figure 1. Map of the Study Site

Experimental Design.

A simple split-plot design was used to arrange and analyze the various treatments. The two factors to be evaluated by the response of corn and bean plants were the main plot factor of three nitrogen fertilizer levels and the subplot factor of four cropping systems. Nitrogen fertilizer was applied at rates of 0, 60 and 120 kg/ha. The cropping systems consisted of monocropped corn (C), monocropped beans (B) and two intercropping systems of corn and beans. One of the intercrops was planted simultaneously (Is) and in the other intercrop the bean planting was delayed for two weeks (Id). Each treatment was replicated four times and within each of the four large blocks the three fertilizer levels were assigned to a main plot by the use of a random number table. Similarly, each of the four cropping systems was specifically included within each fertilizer plot (Figure 1).

The data were analyzed on the SPSSx MANOVA program. (SPSS Inc., 1983). An example of a job file with complete commands is shown in Appendix I. The analysis of variance table for each response variable analyzed, shows whether the two factors were significant independently or as an interaction. Whenever the P-value of the F-ratio was greater than

0.10 for, either of the factors singly or as an interaction, it was assumed that real significant pair-wise differences did not exist. However when a factor had an F-ratio large enough to decrease the P-value of the F-ratio to less than 0.10, pair-wise t-tests were completed according to the procedure of Cochran and Cox (1957) for split plot designs. Because of the limitations of multiple range tests (O'Neil and Wetherhill, 1971), particularly with respect to split plot designs, the ranges of pair-wise t-tests were corrected using the Bonferonni Correction Factor (Miller, 1977). The desired P-value was divided by the number of pair-wise t-tests within any given group. Groups were designated as all cropping systems within one fertilizer level or as combined cropping systems calculated as averages over all fertilizer levels. Similarly comparisons between fertilizer levels were within groups of one cropping system or combined over all cropping systems. Therefore a response variable which included four cropping systems was analyzed by correcting for six possible pair-wise t-tests within each fertilizer level.

It should be noted that if the interaction of cropping systems with fertilizer levels was not significant, there was an indication that the two factors were tending to be parallel, i.e. for every change from one cropping system to another at a given

fertilizer level, the change between those cropping systems at another level of fertilizer would tend to be the same or vice versa. When the interaction of cropping systems x fertilizer levels was significant, only two pair-wise t-tests were calculated for response variables including corn. Is-60 N and Id-60 N were both compared to C-120 N. These tests were based on a priori hypotheses and therefore the P-value was not corrected by use of the Bonferonni Correction Factor.

A significance level of 0.10 was judged acceptable to detect differences in field trials for the overall F-ratios or the P-values of pair-wise t-tests. There tends to be a high propensity for variation in field trials and the null-hypothesis should not be accepted too quickly with the risk of ignoring possible real differences. However when differences were significant at levels of 0.05 or less or 0.01 or less, they were noted.

Calculations to determine the dry weight of plant parts in a plot involved the multiplication of the plot wet weight by the proportional weight of the subsample which was oven dried and compared to its original wet weight. The total nitrogen of any given plant part was determined by multiplying the dry weight by its percentage nitrogen divided by 100. The total nitrogen of corn silage involved the calculation of the total

nitrogen in plant parts and then these were summed.

A Land Equivalent Ratio (LER) was calculated for each intercrop with the dry weight of the harvested crop or silage as the basis of comparison. In addition an LER was determined with the weight of total nitrogen and an LER was also calculated according to the current monetary value of the crops. An LER can be calculated with several methods although the most common is;

$$LER = Y_a/S_a + Y_b/S_b \quad \text{Eqn. 1} \quad (\text{Willey, 1979a})$$

Y_a, Y_b = the yield of crop a or b in an intercrop

S_a, S_b = the yield of crop a or b as a sole crop.

This index involves the same ratios as the Relative Yield Totals of deWit and van den Bergh (1965).

Another method of LER determination which accounts for the proportional competitiveness of each crop is as follows;

$$LER = (Y_a + Y_b)/(pS_a + pS_b) \quad \text{Eqn. 2}$$

(Willey and Osiru, 1972)

pS_a, pS_b = proportion of crop a or crop b which was harvested in an intercrop, times the yield of sole crop a or sole crop b.

An indicator similar to an LER is a yield ratio (YR) which is sometimes used to compare an intercrop to one sole crop.

$$YR = (Y_a + Y_b)/S_a \quad \text{Eqn. 3} \quad (\text{Willey, 1979a})$$

This yield ratio is used when intercrop yields of crop a (Y_a) + crop b (Y_b) are expected to be higher than the yield of sole crop a (S_a).

The monetary value of corn was assumed to be \$25/tonne wet weight adjusted to the mean dry weight of corn in all treatments. The bean silage was valued on the basis of the amount of actual soymeal nitrogen it replaced. On this basis bean silage was worth \$5.00/kg of nitrogen when 44% protein soymeal was \$350.00/tonne. Since cattle can synthesize protein from both inorganic and organic nitrogen the conversion of 1 part of plant nitrogen to 6.25 parts of soymeal protein seemed to be appropriate (Kass, 1978).

$$\$350.00 / (1000 \text{ kgN} \times 0.44 / 6.25) = \$5.00/\text{kgN}$$

Eqn. 4

The cost effectiveness values were determined similarly for corn and bean silage, and costs of nitrogen fertilizer were valued at \$48.00 per 60kg of actual N, while the pole bean seed cost \$29.40/ha. The following equation summarizes the calculations to determine the net value per hectare of corn and/or bean silage in a given treatment before expenses which were common to each treatment.

$$\begin{aligned} \text{Net \$ / ha} &= \text{AWWCsil } (\$25.00) + \text{TNBsil } (\$5.00) \\ &- \text{BSe } (\$29.40) - \text{UFL } (\$48.00) \end{aligned} \quad \text{Eqn. 5}$$

AWWCsil = Adjusted Wet Weight of Corn Silage (kg)

TNBsil = total nitrogen of bean silage (kg)

BSe = bean seeds (BSe = 0 or 1)

UFL = # of units of 60 kg of fertilizer

(UFL = 0, 1, 2)

Results

The results are presented in three parts and are organized to answer the four questions of the experimental design. The first part shows comparisons of biomass and nitrogen in corn and bean plants between cropping systems at given levels of fertilizer. LER values are considered in the second part, calculated by two methods. The third part consists of a cost effectiveness comparison of treatments.

The response variables used to determine differences between treatments were the weight of corn silage (WCsil), bean silage (WBSil), total silage (WTsil), corn roots (WCR); the total nitrogen of corn silage (TNCsil), bean silage (TNBSil), total silage (TNTsil), corn kernels (TNCK), bean roots (TNBR); the percentage nitrogen of corn silage (PNCsil), bean silage (PNBSil), total silage (PNTsil), corn kernels (PNCK), bean seeds (PNBSe), corn leaves (PNCL), corn stalks (PNCSt), bean roots (PNBR); and the ppm of total mineralized nitrogen in soil (TMNS). For any given response variable the means of cropping systems are compared within one level of fertilizer or the combined means of cropping systems are compared as averaged over all levels of fertilizer. In all cases the means of fertilizer levels were found to follow an increasing trend from 0 N to 60 N to 120 N for each cropping

system or when combined and averaged over all cropping systems. In all but one case, to be noted later, where an exception to this trend was found, the pairs of means were determined not to be significantly different at a P-value of 0.10. Type II Errors may be possible but further testing of power was not done as one would expect that enough experiments have been completed to show that plant weights and nitrogen contents respond positively to increased N fertilizer application. It was not intended in the study to test this hypothesis but to check, as a precaution, whether the trend was evident. Several pair-wise t-tests of Is-60 N vs. C-120 N and Id-60 N vs. C-120 N were calculated but these were across fertilizer levels and cropping systems to test specific interactions.

The weight of corn silage (includes all above-ground plant parts) was significantly greater in the C treatment than either Is or Id at any given fertilizer level (Table 3). It is apparent in Figure 2 that at all levels of fertilizer, Id is greater than Is, however this difference is significant only at 120 N and when combined over all fertilizer levels. Note that each bar in Figures 2-12 has each of the four replications or actual values of individual plots represented by short dashes immediately to the right of the bars. In testing the a priori hypothesis to

Figure 2

Weight of Corn Silage (WCsil)

The weight of corn silage is represented for 3 cropping systems (C, Is, Id) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 2:

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	65877.24	6	10931.21		
FL	236262.91	2	118131.46	10.8068	.010
Blocking	96277.19	3	32075.73	2.9343	.121
Error 2	135213.89	18	7511.88		
CS	1196982.31	2	598491.15	79.67266	.000
CS x FL	85069.26	4	21267.31	2.8312	.055

determine whether there is a difference between C-120 N and either Is-60 N or Id-60 N it was shown that for each comparison C-120 N was significantly greater.

The total nitrogen of corn silage (Figure 3) demonstrated a very similar pattern to that of WCsil. The relatively lower position of C-60 N with TNCsil was not significantly different than Id-60 N and was different with a P-value of 0.10 than Is (Table 3). Otherwise all the significant differences between pairs are the same with TNCsil and WCsil.

Another response variable of interest was the comparative distribution of total nitrogen to the corn kernels. The actual TNCK (Figure 4) shows an identical pattern of response to that of TNCsil with similar significant differences. This implies that the treatments which allocate more nitrogen to the kernels can afford to do so because more is available. A test of the proportion of TNCK to the full amount of TNCsil revealed that no differences occurred between cropping systems at all fertilizer levels confirming that relatively constant proportions of nitrogen moved to kernels regardless of cropping systems. An exception to the trend of increasing response with increasing fertilizer levels was observed with these proportions however. When each fertilizer level was combined over all cropping systems, 0 N and 60 N were each

Figure 3

Total Nitrogen of Corn Silage (TNCsil)

The total nitrogen of corn silage is represented for 3 cropping systems (C, Is, Id) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 3.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	12.667	6	2.111		
FL	78.552	2	39.276	18.604	.003
Blocking	36.562	3	12.187	5.773	.033
ERROR 2	33.011	18	1.834		
CS	154.416	2	77.208	42.099	.000
CS x FL	30.650	4	7.662	4.178	.014

Figure 4

Total Nitrogen of Corn Kernels (TNCK)

The total nitrogen of corn kernels is represented for 3 cropping systems (C, Is, Id) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 4.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	5.200	6	.867		
FL	30.197	2	15.099	17.422	.003
Blocking	23.188	3	7.729	8.919	.012
Error 2	15.364	18	.854		
CS	91.292	2	45.646	53.478	.000
CS x FL	14.873	4	3.718	4.356	.012

significantly greater than 120 N (P-value = 0.10; Table 2). Reproductive success may be ensured with the allocation of greater proportions of nitrogen to the kernels when less total nitrogen is available from fertilizer.

The weight and total nitrogen of bean silage were also very similar between treatments (Figures 5 and 6, Table 4). Is was significantly greater than Id, to a greater extent with the WBSil variable than the TNBSil variable at combined cropping systems. Is was not significantly greater than Id at a fertilizer level of 120 N with the TNBSil variable. All other differences between pairs were of similar significance with each of WBSil and TNBSil. The predominant observation with these variables is that the B treatment was significantly greater at all fertilizer levels.

When the total silage from each cropping system was analyzed as one variable for weight, another for percentage nitrogen and a third for total nitrogen, the merging of effects on corn and beans was apparent. WTSil (Figure 7) and WCSil responded to the treatments similarly, the major difference with WTSil being the additional comparison to the sole bean treatment which was always significantly less than any other cropping system at all fertilizer levels (Table 5). At 0 N and 120 N, sole corn was significantly greater than Is or

Table 2

Means of Proportion of TNCK to TNCsil

	0 N	60 N	120 N
C	.78741	.76254	.72095
Is	.74917	.75033	.73254
Id	.74806	.76196	.71270
ComFL	.76155	.75828	.72206

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	.004	6	.001		
FL	.012	2	.006	8.833	.016
Blocking	.020	3	.007	10.344	.009
Error 2	.026	18	.001		
CS	.002	2	.001	.605	.557
FL x CS	.003	4	.001	.599	.668

For Combined Fertilizer Levels (ComFL) 0 N and 60 N
are each significantly greater than 120 N ($P = 0.10$).

Figure 5

Weight of Bean Silage (WBSil)

The weight of bean silage is represented for 3 cropping systems (Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 5.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	3819.492	6	636.582		
FL	21600.849	2	10800.425	16.966	.003
Blocking	30948.271	3	10316.090	16.205	.003
Error 2	15422.730	18	856.818		
CS	509333.593	2	254666.797	297.224	.000
CS x FL	19400.964	4	4850.241	5.661	.004

Figure 6

Total Nitrogen of Bean Silage (TNBsil)

The total nitrogen of bean silage is represented for 3 cropping systems (Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 6.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	4.286	6	.714		
FL	32.079	2	16.039	22.455	.002
Blocking	45.342	3	15.114	21.159	.001
Error2	15.931	18	.885		
CS	341.090	2	170.545	192.695	.000
CS x FL	19.044	4	4.761	5.379	.005

Figure 7

Weight of Total Silage (WTsil)

The weight of total silage is represented for 4 cropping systems (C, Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance applies to Figure 7..

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	4260683.1	6	710113.9		
FL	27972389.3	2	213986194.7	19.696	.002
Blocking	16759957.7	3	5586652.6	7.867	.017
Error 2	17496583.9	27	648021.6		
CS	430278135.9	3	143426045.3	221.329	.000
CSxFL	11632501.1	6	1938750.2	2.992	.023

Id but at 60 N, sole corn was not significantly different than Id and was only greater than Is at 0.10 (P-value). C-120 N was significantly greater than Is-60 N or Id-60 N. The two intercrops were not significantly different at 0 N and 60 N but the Id treatment was significantly greater than Is at 120 N (P-value = 0.05) and this was reflected in the combined Id being greater than the combined Is with a P-value of 0.10.

Not surprisingly the PNTsil response (Figure 8) was opposite to that of WTsil. The sole bean treatments at all fertilizer levels were significantly greater than any other cropping system. At every fertilizer level except 0 N the intercrops Id and Is were significantly greater than sole corn. Perhaps the most interesting observation is that the total silage had a significantly higher percentage nitrogen at Is-60 N than C-120 N (P-value = 0.05). The two intercrops were not significantly different for the PNTsil variable with a P-value of 0.10 (Table 5).

The total nitrogen (derived from weight and percentage nitrogen) of the total silage indicates that the higher percentage nitrogen of beans and the greater weight of corn when joined in one variable, reduce differences between cropping systems (Figure 9). There was significantly more TNTsil in sole corn than sole

Figure 8

Percentage Nitrogen of Total Silage (PNTsil)

The percentage nitrogen of total silage is graphed for 4 cropping systems (C, Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 8.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	.0595	6	.0099		
FL	.4015	2	.2008	20.2568	.002
Blocking	.5033	3	.1678	16.9283	.002
Error 2	.3780	27	.0140		
CS	19.1219	3	6.3740	455.2761	.000
CS x FL	.1654	6	.0274	1.9588	.107

Figure 9

Total Nitrogen of Total Silage (TNTsil)

The total nitrogen of total silage is represented for 4 cropping systems (C, Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 9.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	651.89	6	108.65		
FL	14529.64	2	7264.82	66.865	.000
Blocking	11794.47	3	3931.49	36.185	.000
Error 2	6043	27	232.87		
CS	323.42	3	893.14	3.835	.021
CS x FL	5447.85	6	907.97	3.899	.006

beans at all fertilizer levels except 60 N. Id-120 N was significantly greater than B-120 N which caused a similar effect when cropping systems were combined over all fertilizer levels (Table 5). C-120 N in this case was significantly greater than Id-60 N but not significantly greater than Is-60 N. All other differences were not significant for TNTsil.

The variables, PNCsil and PNBsil indicated that significant differences were not evident between treatments (Table 6). The cropping system factor did not have a sufficiently large F-ratio to warrant further testing for either variable. Differences were not significant at a level of 0.10 so the null hypothesis could not be rejected. It seems that of the cropping systems utilized, no effect on the percentage nitrogen occurs between treatments with corn silage or bean silage. To test further for circumstantial evidence that nitrogen may move from beans to corn, additional variables were tested with the MANOVA program. Regardless of the corn plant indicators tested, corn in intercrop treatments never had a significantly greater percentage nitrogen value than sole corn. The variables separately tested for this purpose were; September harvested corn kernels, leaves and stalks as well as corn leaves and stalks sampled from the edges of plots in June, July and August. Without exception,

the F-ratio for the cropping system factor was not large enough to be significant at 0.10, for all variables (Table 6).

Roots were considered apart from bean and corn silage to avoid confusion about what a farmer could reasonably harvest and also to note specifically the region of competition and/or beneficial effects between corn and bean plants with respect to water and nutrients. One should be cautious about attaching too much importance to these results because of difficulties in uniformly sampling roots from each plot. An attempt was made to extract the main clumps of roots without varying the volume of soil removed with each root. Consistency seemed to be lacking in this regard. It was also unlikely that the sticky clay was washed from each root to the same extent although this was intended.

Despite some difficulties of procedure the WCR does show conclusively that at all fertilizer levels except at 0 N, sole corn was significantly greater than either Is or Id, and that C-120 N was significantly greater than Is-60 N or Id-60 N (P-values=0.01; Figure 10, Table 3). All other differences were not significant with a P-value of 0.10.

The bean roots were tested for WBR and TNBR and

Figure 10

Weight of Corn Roots (WCR)

The weight of corn roots is represented for 3 cropping systems (C, Is, Id) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 10.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	2211.35	6	368.56		
FL	2143.80	2	1071.90	2.908	.131
Blocking	4695.487	3	1565.162	4.247	.063
Error 2	4109.87	18	228.33		
CS	9536.58	2	4768.29	20.884	.000
CS x FL	2052.78	4	513.20	2.248	.104

found to have identical patterns of response. At all fertilizer levels sole beans were significantly greater than Is or Id but differences were not statistically detectable between Is and Id (Figure 11, Table 4). The PNBR showed no significant differences between treatments for most pairs but at 120 N and with combined cropping systems over all fertilizer levels the sole beans were significantly greater than the Id treatment.

One would expect the available soil nitrogen to also be an indicator of treatment effects. The total mineralized nitrogen of the summed ppm of nitrate and ammonia in the soil at the time of harvest revealed few significant differences (Figure 12, Table 5). At a fertilizer level of 120 N and over all fertilizer levels, Id was significantly greater than Is and over all fertilizer levels, B was significantly greater than Is.

The LER values (Table 7) show results for two methods and three criteria of assesment. Method 1 would be the most traditional practice for calculating an LER (Willey, 1979a). Willey and Osiru (1972) proposed Method 2 as a response to criticisms about the necessity to compare intercrops to sole crops in their competitive proportions. Method 2 tends to produce more conservative LER values.

Figure 11

Total Nitrogen of Bean Roots (TNBR)

The total nitrogen of bean roots is represented for 3 cropping systems (Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The following analysis of variance data applies to Figure 11.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS _s	DF	MS	F-ratio	P-value
Error 1	.001	6	.000		
FL	.001	2	.000	1.695	.261
Blocking	.003	3	.001	4.116	.061
Error 2	.004	18	.000		
CS	.033	2	.016	74.482	.000
CS x FL	.001	4	.000	.825	.526

Figure 12

Total Mineralized Nitrogen in the Soil (TMNS)

The total mineralized nitrogen in the soil is graphed for 4 cropping systems (C, Is, Id, B) with each level of N fertilizer (0, 60, 120 kg/ha). The analysis of variance data applies to Figure 12.

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	27.225	6	4.538		
FL	22.293	2	11.146	2.45650	.166
Blocking	17.968	3	5.989	1.31998	.352
Error 2	40.037	26	1.540		
CS	22.950	3	7.650	4.96785	.007
CS x FL	6.616	6	1.103	.71603	.640

The six cells of LER values from Table 7 can be roughly divided into two groups. The more successful group of Is-60 N, Id-60 N and Id-120 N had five advantageous LER values (> 1.0) per cell. In the other group Id-0 N and Is-120 N had three advantageous LER values per cell and although Is-0 N had five advantageous LER values, two were very close to one (1.01, 1.03). To consider it another way, note that for a given method and a given currency the LER values of the more successful group were equal to or greater than the less successful group. Again the Is-0 N treatment had several exceptions to indicate that it didn't easily comply with this apparent organization. The treatment with the highest results was Is-60 N which had values for any given method or currency equal to or greater than any other treatments, without exception. Of special interest were the LER values for total nitrogen which were 1.18 and 1.17 respectively, with Method 1 and Method 2.

In most cells the LER values of silage corresponded quite closely with monetary values. The total nitrogen LER values of Is-60 N and Id-60 N were higher than either of the other currencies for Method 1 and Method 2. In contrast, the total nitrogen LER values of the less successful group (Is-0 N, Id-0 N, Is-120 N) were lower than the other currencies for

Method 1. Id-120 N did not conform to either pattern but indicated a close correspondance between total nitrogen and monetary values with both methods.

The two methods of LER calculation corresponded reasonably well with the yield ratio (YR; Table 7). This yield ratio followed the trend of increases or decreases of the LER values from one currency to another within all cells with one exception in each of Is-120 N and Id-120 N. The tendency of Is-60 N, Id-60 N and Id-120 N to belong to a more successful group was also supported by the YR, as was the highest rating of Is-60 N, using assessments similar to those discussed above for LER values.

The cost effectiveness of intercropping (Table 8) was compared within intercropping treatments and to C, especially C-120 N which represents a common agricultural practice. The gross value of Id-120 N was higher than C-120 N, however C-120 N was most cost effective when the costs of fertilizing and bean seeds were subtracted. Id-120 N and Is-60 N were within 5% of the effectiveness of C-120 N and it is interesting to note that C-0 N was only \$53/ha less cost effective than C-120 N, although another field with less residual N from previous years might produce different results.

Table 3

Differences : Corn Response Variables

Pair wise Differences		WCsil	TNCsil	WCR	TNCK
ON	Is-C	-(***)	-(***)	NS	-(***)
	Id-C	-(***)	-(***)	NS	-(***)
	Id-Is	NS	NS	NS	NS
60N	Is-C	-(***)	-(*)	-(***)	-(**)
	Id-C	-(***)	NS	-(**)	NS
	Id-Is	NS	NS	NS	NS
120N	Is-C	-(***)	-(***)	-(***)	-(***)
	Id-C	-(***)	-(***)	-(***)	-(***)
	Id-Is	+(***)	+(***)	NS	+(**)
ComCS	Is-C	-(***)	-(***)	-(***)	-(***)
	Id-C	-(***)	-(***)	-(***)	-(***)
	Id-Is	+(***)	+(**)	NS	+(**)
Is60N-C120N		-(***)	-(***)	-(***)	-(***)
Id60N-C120N		-(***)	-(***)	-(***)	-(***)

ComCS = Combined Cropping Systems

* Significant at P-value of 0.10

** Significant at P-value of 0.05

*** Significant at P-value of 0.01

NS Not a Significant Difference

Differences are + or -

Table 4

Differences : Bean Response Variables

Pair wise Differences		WBSil	TNBSil	TNBR	PNBR
ON	Is-B	-(***)	-(***)	-(***)	NS
	Id-B	-(***)	-(***)	-(***)	NS
	Id-Is	NS	NS	NS	NS
60N	Is-B	-(***)	-(***)	-(***)	NS
	Id-B	-(***)	-(***)	-(***)	NS
	Id-Is	-(*)	-(*)	NS	NS
120N	Is-B	-(***)	-(***)	-(***)	NS
	Id-B	-(***)	-(***)	-(***)	-(**)
	Id-Is	-(*)	NS	NS	NS
ComCS	Is-B	-(***)	-(***)	-(***)	NS
	Id-B	-(***)	-(***)	-(***)	-(***)
	Id-Is	-(***)	-(**)	NS	NS

ComCS Combined Cropping Systems
 * Significant at P-value of 0.10
 ** Significant at P-value of 0.05
 *** Significant at P-value of 0.01
 NS Not a Significant Difference
 Differences are + or -

Table 5

Differences : Total Silage and Soil
Response Variables

Pair wise Differences		WTsil	TNTsil	PNTsil	TMNS
ON	Is-C	-(***)	NS	NS	NS
	Id-C	-(***)	NS	NS	NS
	Id-Is	NS	NS	NS	NS
	Is-B	+(***)	NS	-(***)	NS
	Id-B	+(***)	NS	-(***)	NS
	C-B	+(***)	+(**)	-(***)	NS
60N	Is-C	-(*)	NS	+(***)	NS
	Id-C	NS	NS	+(*)	NS
	Id-Is	NS	NS	NS	NS
	Is-B	+(***)	NS	-(***)	NS
	Id-B	+(***)	NS	-(***)	NS
	C-B	+(***)	NS	-(***)	NS
120N	Is-C	-(***)	NS	+(*)	NS
	Id-C	-(***)	NS	+(*)	NS
	Id-Is	+(**)	NS	NS	+(**)
	Is-B	+(***)	NS	-(***)	NS
	Id-B	+(***)	+(***)	-(***)	NS
	C-B	+(***)	+(***)	-(***)	NS
ComCS	Is-C	-(***)	NS	+(***)	NS
	Id-C	-(***)	NS	+(**)	NS
	Id-Is	+(*)	NS	NS	+(**)
	Is-B	+(***)	NS	-(***)	-(**)
	Id-B	+(***)	+(*)	-(***)	NS
	C-B	+(***)	+(**)	-(***)	NS
Is60N-C120N		-(***)	NS	+(**)	NS
Id60N-C120N		-(***)	-(**)	NS	NS

ComCS Combined Cropping Systems
 * Significant at P-value of 0.10
 ** Significant at P-value of 0.05
 *** Significant at P-value of 0.01
 NS Not a Significant Difference
 Differences are + or -

Table 6

F-value and Significance of F of PN Variables

Response Variable	Source of Variation	DF	F-ratio	P-value
September				
PNBSe	FL	2	86.583	.000
PNBSe	CS	2	.074	.929
PNBSe	FL x CS	4	3.127	.041
PNBR	FL	2	16.932	.003
PNBR	CS	2	5.892	.011
PNBR	FL x CS	4	.453	.769
PNCK	FL	2	10.377	.011
PNCK	CS	2	.818	.457
PNCK	FL x CS	4	5.035	.007
PNCL	FL	2	19.500	.002
PNCL	CS	2	.018	.983
PNCL	FL x CS	4	.432	.783
PNCSt	FL	2	3.162	.115
PNCSt	CS	2	.538	.593
PNCSt	FL x CS	4	1.231	.333
August				
PNCK	FL	2	4.846	.056
PNCK	CS	2	2.469	.113
PNCK	FL x CS	4	1.115	.380
PNCL	FL	2	.331	.731
PNCL	CS	2	2.284	.131
PNCL	FL x CS	4	1.753	.182
PNCSt	FL	2	8.688	.017
PNCSt	CS	2	2.505	.110
PNCSt	FL x CS	4	.379	.821
July				
PNCL	FL	2	6.382	.033
PNCL	CS	2	1.501	.249
PNCL	FL x CS	4	1.276	.316
PNCSt	FL	2	5.299	.047
PNCSt	CS	2	1.203	.323
PNCSt	FL x CS	4	1.099	.387
June				
PNCL	FL	2	5.763	.040
PNCL	CS	2	.129	.880
PNCL	FL x CS	4	3.016	.046

Table 7

LER and YR

Currency/		Is-sil (kg)	Is-TN (kg)	Is-cash (\$)	Id-sil (kg)	Id-TN (kg)	Id-cash (\$)
FL	Eqn.						
0 N	M1	1.12	1.03	1.12	1.06	0.94	1.05
	SD	$\pm .11$	$\pm .16$	$\pm .12$	$\pm .24$	$\pm .41$	$\pm .26$
0 N	M2	0.89	1.01	1.08	0.89	0.91	1.02
0 N	YR	0.77	0.90	0.95	0.81	0.81	0.94
60 N	M1	1.12	1.18	1.12	1.08	1.09	1.06
	SD	$\pm .07$	$\pm .10$	$\pm .05$	$\pm .09$	$\pm .09$	$\pm .09$
60 N	M2	0.99	1.17	1.12	0.98	1.09	1.06
60 N	YR	0.88	1.24	1.12	0.91	1.13	1.06
120 N	M1	1.02	0.98	1.04	1.06	1.10	1.11
	SD	$\pm .03$	$\pm .05$	$\pm .03$	$\pm .04$	$\pm .08$	$\pm .09$
120 N	M2	0.81	0.96	1.02	0.91	1.08	1.09
120 N	YR	0.70	0.85	0.92	0.83	1.00	1.02

M1 = Méthod 1, M2 = Method 2,
SD = Standard Deviation,

Table 8

Dollar Value of Crop per Hectare

Treatment	Gross $\pm$ SD (\$)	Net (\$)
C-0 N	595 $\pm$ 29	595
C-60 N	620 $\pm$ 76	572
C-120 N	743 $\pm$ 45	647
Is-0 N	565 $\pm$ 38	536
Is-60 N	694 $\pm$ 69	617
Is-120 N	683 $\pm$ 80	558
Id-0 N	557 $\pm$ 152	528
Id-60 N	658 $\pm$ 112	580
Id-120 N	755 $\pm$ 51	629

Net = Gross minus fertilizer and/or bean seeds
SD = Standard Deviation

Discussion

"The basic problems with research on mixed cropping are that it is a very complex area to investigate and, as a result, is very expensive and time consuming to undertake. A large number of variables influence the physical yield of sole crops and this becomes considerably more complex in a mixed cropping situation because of the possible interactions involved." (Norman, 1976)

The relative merits of intercropping in this study were not as obvious as in some others. For example the LER values of biomass ranged around 1.10 which was a marginal advantage compared to LER values similarly calculated with the same crops in the tropics where LER values of 1.50 and higher were common (Francis et al., 1982b, 1982c; Risch and Hansen, 1982; Remison, 1978; Osiru and Willey, 1976). Possible reasons for the less than expected advantages of intercropping in temperate regions are as follows: 1) The density and/or spacing of the component crops may not have been optimal and may have required adjustments (Martin and Snaydon, 1982a; Francis et al., 1982b, 1982c, 1978a, 1978b; Willey, 1979a; Kass, 1978). 2) Poles beans may not be

the most suitable legume for intercropping with silage corn at this latitude (Wiggans, 1935). 3) The climatic conditions may have been too cool and wet in May 1983 for optimal bean dinitrogen fixation (Rennie and Kemp, 1981). 4) The varieties of hybrid corn and beans used, may not have been appropriate for intercropping (Francis et al., 1983; Rao and Willey, 1983; Wahua et al., 1981; Mead and Willey, 1980). 5) This latitude and/or its regional climatic peculiarities may not represent an ideal intercropping environment (Sale, 1975; Bunting, 1974; Virtanen and Miettinen, 1963; Wilson and Wyss, 1937). 6) The beans may not have been shaded enough to stimulate excretion of nitrogen from the nodules (Sale, 1975; Virtanen and Miettinen, 1963; Wilson and Wyss, 1937). 7) The maturity periods and peak resource demand periods of the two component crops may have been too close (Waghmare and Singh, 1984; Osiru and Willey, 1976; Baker, 1974).

In spite of these possible inhibitory effects on differences between the experimental treatments it is valid to discuss biological interpretations of the results as observed. The reduced biomass of corn and bean silage when intercropped was to be expected. Competition plays a vital role, whether the cropping system involves a monocrop or an intercrop (Harper, 1977), and it is obvious that competition was

relatively increased when more plants were added to a monocrop to form an intercrop. WCsil responded according to expected results: with highest yields from C; lower yields from Id as competition was increased; and lowest yields from Is in which case the competition was most severe for the corn (Knapp, 1982). On the other hand WBSil was observed to have higher values with the Is as opposed to the Id treatments and this is reasonable since the beans were subject to less competition when planted at the same time rather than after corn seedlings had become established (Francis et al., 1982a).

It is possible that WCsil was not significantly different between Is and Id at 0 N because competition was more pronounced with only residual soil N to share and was beyond the scope of correction by cropping system manipulations. This reasoning might also apply to the intercrops and the WBSil variable at 0 N. At 60 N with less nitrogen restriction, one would expect the WCsil variable to be significantly greater in the Id treatment than Is. The beans may have been able to fix more nitrogen when intercropped simultaneously and therefore may have competed less for limited applied nitrogen than the more stressed beans of Id. The fact that the TNBSil at 60 N was significantly greater for Is as compared to Id seems to substantiate this

proposal.

Not to ignore statistical considerations, it is worthwhile noting that whenever there is speculation about the lack of significant differences one must question whether the power of the experiment was sufficient to detect a difference. The possibility of a Type II Error, when there is a failure to reject the null hypothesis, is always present (Scheffler, 1979).

The total nitrogen of corn and bean silage was not unexpectedly, a reflection of the biomass. The relatively heavy weighting of the large biomass numbers as compared to the percentage N numbers, divided by 100, in the calculation of TN accounts for much of the correlation (e.g. $C-120\ N, TNCK(109.7) = WCK(5927.3) \times PNCK(1.85)/100$). The fact that TNCsil at 60 N showed an absence of, or less significant differences than WCsil may be as a consequence of the amplification of the range of means by percentage nitrogen when multiplied by the weight. That Is was significantly greater than Id, for WBSil but not for TNBSil at 120 N may be explained by the logic of the above statement or the suggestion that Id beans were not as restricted in their own fixation of N by the high level of N fertilizer due to the prior uptake of rapidly growing corn.

The relative success of corn crops is related to their capacity to allocate as much N as possible to the kernel sink compartment (Anderson et al., 1984; Tsai et al., 1984; Crawford et al., 1982; Ivanko, 1979) and it therefore was important to investigate the response of TNCK to the main effects. Analysis showed that the absolute amount of TNCK was correlated to that TN which was available in corn silage. The movement of N from other plant parts such as the stalk and leaves appears to have been more influential than plant uptake from the soil, although labelled N would have to be employed to confirm this previously observed trend by Crawford et al. (1982). It seems reasonable to assume that since TNCK distribution as a proportion of TNCSil was significantly greater with each successive decrease of fertilizer levels, therefore as competition increased, the corn plant allocated more proportional N of the total plant to the kernel for maximum reproductive opportunities. Noting that there were no significant differences of TNCK proportional distribution by cropping systems one might speculate that competition from intercropping was less severe than from reduced N fertilization.

The circumstantial evidence to indicate that the nitrogen can be transferred from beans to corn was looked for in the PNCsil response variable. A higher

percentage nitrogen in intercropped corn than in monocropped corn would suggest that the intercropping treatment was responsible for the increase and possibly because nitrogen was being transferred from bean nodules. The potential of free-living fixers to contribute to the corn (Postgate, 1982; Ruschel et al., 1979; Sprent, 1979) may also be stimulated by an intercrop.

The percentage nitrogen for all corn plant parts tested was not significantly different between cropping systems but in many cases differences were significant with increases of fertilizer levels. This tends to support the argument that applied fertilizer N is more influential than cropping systems as observed by the response of nitrogen within corn plants. It also suggests that if there is a phenomenon of nitrogen transfer from beans to corn, this transfer is of no practical magnitude and could be diluted with current heavy fertilization practices (Eaglesham et al., 1981). Significant differences were not seen with TMNS at 0 N between cropping systems either. However the residual nitrogen in the soil from previous cropping systems must be considered substantial since 0 N treatments were not significantly different than 60 N or 120 N. Although corn in any cropping system will respond to more fertilizer N it seems that beans cannot have an

immediate impact unless there is such a limited amount of soil nitrogen that a transfer is relatively significant (Eaglesham et al., 1981). It may also be possible to fine tune the balance of competition and complementarity with spacing and/or population density such that intercropped corn at an intermediate level of fertilizer may reflect positive effects of increased percentage nitrogen. This trend, although not significant, is evident in Table 9 where PNCsil is greater for Is and Id than C at 60 N. Questions about adjustments which could amplify this trend seem worthy of more research. Even if this trend was significant however, the transfer of nitrogen would be only one of several possible contributors.

It is important to remember that this was a study about competition and complementarity between two crops. Competition can be considered to be direct interference or mutual exclusivity with respect to a limited resource. Complementarity may be viewed as a non-interference strategy whereby plants utilize resources without depleting availability to neighbouring plants (Bouldin et al., 1979; Trenbath, 1974; Agboola and Fayemi, 1972) or complementarity may be a disruptive influence on negative effects to neighbouring plants (van Rheenen et al., 1980) or it may involve direct beneficial effects, such as the

Table 9

PNCsil Means and Replications

	FL	0 N		60 N		120 N	
CS	Mean	Reps	Mean	Reps	Mean	Reps	
C	.9979	1.0502	.9242	1.0399	1.1164	1.1516	
C		1.0442		.9944		1.1454	
C		.9686		.8431		1.1230	
C		.9288		.8194		1.0457	
Is	.8646	.9583	1.0017	1.0586	1.0046	1.1660	
Is		.8512		1.0215		1.0538	
Is		.8395		1.0053		.9585	
Is		.8093		.9214		.8340	
Id	.7981	1.0379	.9657	1.0769	1.1015	1.2117	
Id		.8666		1.0567		1.0789	
Id		.6605		.9106		1.0627	
Id		.6274		.8185		1.0528	

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	.023	6	.004		
FL	.213	2	.106	28.226	.001
Blocking	.151	3	.050	13.366	.005
Error 2	.132	18	.007		
CS	.026	2	.013	1.758	.201
FL x CS	.099	4	.025	3.349	.032

transfer of nitrogen from legumes to corn (Eaglesham et al., 1981; Nowotnowna, 1937; Thornton and Nicol, 1934; Lipman, 1912). Intercropping is frequently advantageous to the extent that complementarity can be enhanced for one or both component crops. Any given corn plant will experience competition from other corn plants as well as beans but usually farmers accept competition on an individual plant basis to ensure that available resources are efficiently used by the whole crop. It is preferable to have available N taken up by the crop and have some plants inhibit uptake by others than to risk the loss of this N by leaching because too few plants were present (Yadav, 1982).

As legumes, beans probably should be stressed by competition for nitrogen to necessitate more fixation (Sprent, 1979; Henzell and Vallis, 1977). However fixation requires energy and carbohydrates and too much competition could also reduce legume ability to supply rhizobia with sufficient raw materials (Nambiar et al., 1983; Postgate, 1982). In this light, the PNBSil (Table 10) responded predictably, although not to the degree that differences between treatments were significant. At 0 N, each cropping system was stressed although Id showed this more. With the reduction of competition by applying 60 kgN/ha, the Is beans were subjected to less competition than Id beans but

Table 10

PNBsil Means and Replications

	FL	0 N		60 N		120 N	
CS	Mean	Reps		Mean	Reps	Mean	Reps
Is	2.434	2.787		2.752	3.181	2.795	3.045
		2.545			2.826		3.013
		2.206			2.548		2.616
		2.198			2.453		2.507
Id	2.352	2.582		2.485	2.862	3.095	3.201
		2.510			2.644		3.126
		2.298			2.293		3.043
		2.018			2.141		3.011
B	2.421	2.618		2.689	2.865	2.664	3.029
		2.369			2.681		2.852
		2.367			2.654		2.457
		2.328			2.555		2.317

Tests of Significance Using Sequential Sums of Squares

Source of Variation	SS	DF	MS	F-ratio	P-value
Error 1	.055	6	.009		
FL	1.212	2	.606	66.315	.000
Blocking	1.123	3	.374	40.954	.000
Error 2	.585	18	.032		
CS	.031	2	.016	.485	.624
FL x CS	.531	4	.133	4.087	.016

possibly were stressed just enough to produce slightly more nitrogen than sole beans. The next increment of fertilizer level may have inhibited Is bean N fixation and was probably taken up by the corn and beans very competitively. The Id beans may have lagged behind the corn enough to allow adequate uptake of N by corn and consequent minimal inhibition of N fixation. Sprent (1979) explains that the presence of combined nitrogen can accelerate nodule senescence. Without any evidence one might speculate that the nodules of Is-120 N beans senesced too quickly whereas the nodules of Id-120 N beans were able to develop to be larger and more effective in relatively depleted soil.

Notwithstanding the lack of significance for PNBsil the trend may be meaningful because the LER and cost effectiveness values do establish that Is was the most successful cropping system at 60 N and Id was the most successful intercrop at 120 N and reasonably similar to C-120 N. The treatments of Is-60 N and Id-120 N were relatively positive for corn variables as well which also had the effect of contributing to the success of these intercrops. The mineralized nitrogen in the soil was also most abundant at Id-120 N and it has been suggested that Phaseolus vulgaris may enrich the soil by sloughed off material from roots and nodules or by a possible effect on free-living N-fixers

(Ruschel et al., 1979). The response of PNBsil cannot be directly correlated to these aforementioned values but the interpretation of PNBsil response can be tentatively confirmed.

The total silage analysis also supports the developing argument to explain the success of Is-60 N and Id-120 N. At 60 N WTsil did not respond with a significant difference between C and Id whereas at 0 N and 120 N, C was significantly greater than Is and Id. This was a result of increased yields of corn and beans from 0 N to 60 N with both intercrops, such that WTsil at 60 N is more equal for C, Is and Id. The 60 kg of N fertilizer had less effect on sole corn than the intercrops which were able to respond with greater increases. Even though the Is beans were of higher percentage nitrogen than the Id beans, the extra competitive effect of beans growing with corn was more inhibitory to corn growth and WTsil than when beans were planted later. The significantly higher WTsil yield of Id than Is at 120 N supports the proposal that delayed planting of beans allowed corn to take up adequate nitrogen for optimal growth while not unduly decreasing bean growth.

Bouldin et al., (1979) observed that total nitrogen accumulation of an intercrop is usually greater than that of a monocrop. While this was not

significantly evident in this study other than with Id-120 N with respect to B-120 N, the trend was certainly visible at 60 N, where both intercrops had more TN than sole corn and Is more than sole beans.

The results speak for themselves with respect to PNTsil. The quality of silage from intercropped corn and beans was significantly greater than sole corn silage at 60 N and 120 N and perhaps the only surprise is that this was not evident at 0 N. Possibly competition was too severe at this level, although a check of the percentage nitrogen of total seeds shows that at 0 N Is is significantly greater than C (P-value = 0.10). The noteworthy observation that Is-60 N had a significantly higher PNTsil than C-120 N helps to explain the success of this intercrop when subjected to LER and cost effectiveness analysis. As has been previously noted, increments of 60 kg of N fertilizer usually have more of an effect than cropping systems, however Is-60 N seems to be a successful blend of treatment factors to have overcome this predominant trend.

The advantage of intercropped PNTsil would probably have been increased with higher percentage nitrogen levels in the beans. It is reasonable to assume that with plant breeding the percentage nitrogen of pole beans may be significantly increased as well as

nitrogen fixation capabilities (CIAT, 1981; Graham, 1981). Soybeans have responded well to selection for increased seed protein and nitrogen fixation (H. Valdeng, Agriculture Canada, pers. comm.).

As might be expected, competition from intercropping does limit the growth of individual corn and bean roots if the results, after acknowledged procedural problems, were reasonably accurate. A question to be tested in future studies is whether more equal spacing of seeds as opposed to crowding them in single rows would be beneficial. Indications are that corn yields increased when the corn was planted in 40 cm rows rather than 76 cm rows at the same population (W. Cornoe, Kemptville College of Agriculture and Technology, pers. comm.). If complementarity is primarily a strategy of non-interference with these crops (Bouldin et al., 1979; Trenbath, 1974; Agboola and Fayemi, 1972) one would deduce that separate rows for beans and corn would enhance beneficial association (Martin and Snaydon, 1982a; Kass, 1978). If however, there is a direct beneficial effect of beans on corn, such as the possibility of a nitrogen transfer, one would prefer to keep corn and bean roots as close together as possible (Eaglesham et al., 1981; Willey, 1979a; Virtanen and Miettinen, 1963; Wilson and Wyss, 1937).

In corn rows one metre apart an additional corn plant/m was found to reduce corn yield per plant 5-6 times that of an additional bean plant/m, (planted 15 cm from the corn) and reduced bean yield per plant 2-3 times that of an additional bean plant (Francis et al., 1982b). Perhaps this competitive interference could be alleviated with more equal spacing such that corn and beans could be planted in the same rows but in twice as many rows at the same density. The action of complementarity seems to be more important below ground than above ground (Gregory and Reddy, 1982; Martin and Snaydon, 1982b) and therefore a plan to accommodate increased root growth should be a step in the right direction. This is not to discredit the fact that pole beans by climbing up the corn are also positioned to share light with less competition than if, as bush beans, they were below the corn canopy. Above ground interaction can also be very important (Wahua et al., 1981; Willey and Reddy, 1981; Willey 1979a).

Attempts have been made to test the significance of LER values (Wijesinha et al., 1982; Willey, 1979b) but these tests are controversial because the normal LER (Method 1) is the sum of two ratios. The index is still indicative of relative land use efficiency and in this experiment was shown to concur with other indicators. However, one should be cautious about high

LER values with low yielding crops (Wijesinha et al., 1982; Mead and Willey, 1980).. It is obvious from Eqn. 1 that as the sole crop yields decrease the LER tends to increase. For this reason the LER of 1.12 for Is-0 N may be slightly overrated by having the same LER as Is-60 N for silage and monetary value using Method 1. Method 2 appears to demonstrate the superiority of Is-60 N. The success of the Id-120 N treatment concurs with the findings of Faris et al. (1983) that intercrop systems can respond to fertilizer applications without the loss of advantageous effects realized from intercropping.

Silage to be fed to cattle which can build protein from inorganic and organic nitrogen (J. Atwell, Agriculture Canada, pers. comm.) is worth comparing on the basis of total nitrogen (Bouldin et al., 1979, Kass 1978). The LER currency of TN seems to be a more sensitive indicator than the other currencies. For Is-60 N and Id-60 N, TN was greater than the other currencies using both methods whereas for the less successful treatments the TN was less than the other currencies with Method 1. At the risk of violating accepted practice for calculating an LER when the same level of management is used for intercrops and monocrops (Sanchez, 1976) an LER was derived on the basis of intercropped corn and beans at 60 N being

compared to monocropped corn and beans at 120 N for the TN variable. Method 1 and Method 2 showed LER's of 0.98 and 0.96 respectively on this basis which illustrates a minimal disadvantage of the 1s-60 N treatment compared to the highest input monocrops when total nitrogen is the currency.

The "same level of management" criteria must also be considered when comparing monocropped beans to intercropped beans in all of these LER calculations. The sole beans required a much higher level of management because trellising was necessary. Probably pole beans would never be grown alone for agricultural purposes as they seldom are in Latin America (Francis and Sanders, 1978). However, Francis et al. (1981a, 1982b, 1982c) used the normal LER (Method 1) for their work and it may still be the best index for assessing land use efficiency if one disregards that trellising requires extra management or one includes the cost in a monetary value assessment (Francis and Sanders, 1978). The yield ratio used in this study avoids the problem and has the feature of simply comparing intercrops to the corn crop which farmers usually grow. However farmers do grow or buy other crops to supplement the protein of corn and this yield ratio cannot accommodate this extra complexity, whereas an LER (Method 1 or 2) can include a comparison of one intercropped legume to

the same or another legume commonly grown to produce more protein.

The results of the cost effectiveness analysis reflect some of the other considerations. C-120 N is currently the most cost effective treatment and reflects the greater biomass and subsequent high total nitrogen amounts of monocropped corn. Despite the higher percentage nitrogen of Is-60 N total silage and the apparent complementary growth of corn and beans of Id-120 N where the same level of TNTsil as compared to C-120 N was reached, these two intercrops were slightly less cost effective. Note that the yield ratio of TN for Id-120 N was 1 and that if the cost effectiveness had been calculated on the basis of relative TN in corn silage rather than on a biomass basis, the cost effectiveness of Id-120 N would be the same as C-120 N. Also worthy of note is that a farmer might prefer to have less silage of higher quality with a slightly lower initial overhead cost (Is-60 N) than to have too much silage for use within a year but which still requires more supplemental protein (C-120 N). On the other hand the kj of energy available in corn silage are desirable although it requires more than a hectare of pure stands of legumes and corn to produce the same amount of energy and protein that a hectare of intercropping of these crops could produce (Pimich

and Oesliple, 1974; Thatcher, 1925). Unfortunately energy was not measured in this study and is accounted for only as one component in the biomass of corn silage.

The response of TMNS does not show that intercrops contributed significantly more available nitrogen to the soil than either monocrop. In the Is treatment the least TMNS was present at each fertilizer level and Is was significantly less than Id at 120 N and Id and B over all fertilizer levels. The expectation was that the intercrops and sole beans would increase TMNS compared to sole corn treatments (Knapp, 1982; Ruschel et al., 1979). The non-significant trend of TMNS was at least demonstrative of this prediction when Id and B treatments were compared to sole corn.

The possible benefits of intercropping not measured in these trials are erosion control and soil structure improvement. Since the increase of plant roots and senesced bean leaves will add organic matter to the soil, the structure of the soil should improve, as well as the water-holding capacity and the cation exchange capacity (Brady, 1974). Because of competition, roots may penetrate to greater depths (Willey, 1979a; Trenbath, 1974) and improve soil structure more extensively. Erosion can be controlled by soils of improved structure and better infiltration

capacity as well as by increased vegetative cover to reduce raindrop impact (Brady, 1974). To say that intercropping corn and pole beans has these additional advantages is not open to much dispute but an estimate of the magnitude of advantage would require specific determinations.

As agriculturalists shift their emphasis from maximizing yields and mining the soil to optimizing production within sustainable ecological constraints, intercropping will probably gain credibility. The universal appeal of intercropping is that it has been practiced for centuries by diverse groups of people on several continents (Govinden et al., 1984; Willey, 1979a; Sanchez, 1976). Opportunities to blend this depth of experience with incisive scientific research should be seized posthaste. As with the gleanings of this experiment, gradual progress can be achieved toward more cooperative food production between the environment and people.

Conclusions

- 1) The percentage nitrogen of intercrops was greater than monocropped corn but less than monocropped beans. The Is-60 N treatment was significantly greater than C-120 N on this basis.
- 2) The LER values of Is-60 N were always most advantageous while the LER's of Id-120 N and Id-60 N were also quite advantageous. The other intercrops showed less advantage with less consistency.
- 3) The most cost effective treatment was C-120 N although Id-120 N and Is-60 N were within 5% of this most efficient treatment.
- 4) No significant circumstantial evidence was found to indicate that nitrogen was transferred from beans to corn.
- 5) The weight of corn and beans was greater for each component crop in monocrops than in intercrops.
- 6) The total nitrogen of corn and beans was greater for each component crop in monocrops than in intercrops.
- 7) The weight of the total silage was greater in intercrops than monocropped beans but less than monocropped corn.
- 8) The total nitrogen of the total silage was not

significantly different between intercrops and monocrops except that Id-120 N was greater than B-120 N.

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Appendix

Job File

!JOB

!RES MEM=124

!SPSSX (W=20)

!TITLE 'SPNCSIL'

DATA LIST FREE FILE=AGDATA/

P,

C,F,

MNCR,MNCS,MNCC,MNCK,MNCH,MNCL,MNCT,

MWCR,MWCS,MWCC,MWCK,MWCH,MWCL,MWCT,

MMCR,MMCS,MMCC,MMCK,MMCH,MMCL,MMCT,MMCE,

MNBR,MNBS,MNBP,MNBSE,MNBL,MNSBL,

MWBR,MWBS,MWBP,MWBSE,MWBL,

MMBR,MMBS,MMBP,MMBSE,MMBL,MMTBP,MNS,MSPC,MSPB,

JNCR,JNCS,JNCC,JNCK,JNCH,JNCL,JNCT,

JWCR,JWCS,JWCC,JWCK,JWCH,JWCL,JWCT,

JMCR,JMCS,JMCC,JMCK,JMCH,JMCL,JMCT,JMCE,

JNBR,JNBS,JNBP,JNBSE,JNBL,JNSBL,

JWBR,JWBS,JWBP,JWBSE,JWBL,

JMBR,JMBS,JMBP,JMBSE,JMBL,JMTBP,JNS,JSPC,JSPB,

TNCR,TNCS,TNCC,TNCK,TNCH,TNCL,TNCT,

TWCR,TWCS,TWCC,TWCK,TWCH,TWCL,TWCT,

TMCR,TMCS,TMCC,TMCK,TMCH,TMCL,TMCT,TMCE,

TNBR,TNBS,TNBP,TNBSE,TNBL,TNSBL,

TWBR, TWBS, TWBP, TWBSE, TWBL,
 TMBR, TMBS, TMBP, TMBSE, TMBL, TMTBP, TNS, TSPC, TSPB,
 ANCR, ANCS, ANCC, ANCK, ANCH, ANCL, ANCT,
 AWCR, AWCS, AWCC, AWCK, AWCH, AWCL, AWCT,
 AMCR, AMCS, AMCC, AMCK, AMCH, AMCL, AMCT, AMCE,
 ANBR, ANBS, ANBP, ANBSE, ANBL, ANBSL,
 AWBR, AWBS, AWBP, AWBSE, AWBL,
 AMBR, AMBS, AMBP, AMBSE, AMBL, AMTBP, ANS, ASPC, ASPB,
 SNCR, SNCS, SNCC, SNCK, SNCH, SNCL, SNCT,
 SWCR, SWCS, SWCC, SWCK, SWCH, SWCL, SWCT,
 SMCR, SMCS, SMCC, SMCK, SMCH, SMCL, SMCT, SMCE,
 SNBR, SNBS, SNBP, SNBSE, SNBL, SNSBL,
 SWBR, SWBS, SWBP, SWBSE, SWBL,
 SMBR, SMBS, SMBP, SMBSE, SML, SMTBP, SNS, SSPC, SSPB,
 SANS, SNNS, SAVNS

MISSING VALUES P TO SAVNS(0)

COMPUTE STNCSIL=SWCS*SNCS/100+SWCC*SNCC/100+SWCK*SNCK/100
 +SWCH*SNCH/100+SWCL*SNCL/100+SWCT*SNCT/100

COMPUTE SWCSIL=SWCS+SWCC+SWCK+SWCH+SWCL+SWCT

COMPUTE STNBSIL=SWBS*SNBS/100+SWBP*SNBP/100+SWBSE*SNBSE/100
 +SWBL*SNBL/100

COMPUTE SWBSIL=SWBS+SWBP+SWBSE+SWBL

COMPUTE SWTSIL=VALUE(SWCSIL) + VALUE(SWBSIL)

COMPUTE STNTSIL=VALUE(STNCSIL) + VALUE(STNBSIL)

COMPUTE SPNTSIL=VALUE(STNTSIL)/VALUE(SWTSIL)*100

COMPUTE ATNCSIL=AWCS*ANCS/100+AWCC*ANCC/100+AWCK*ANCK/100
 +AWCH*ANCH/100+AWCL*ANCL/100+AWCT*ANCT/100

```

COMPUTE AWCSIL=AWCS+AWCC+AWCK+AWCH+AWCL+AWCT
COMPUTE ATNBSIL=AWBS*ANBS/100+AWBP*ANBP/100+AWBSE*ANBSE/100
+AWBL*ANBL/100
COMPUTE AWBSIL=AWBS+AWBP+AWBSE+AWBL
COMPUTE ATNTSIL=VALUE(ATNCSIL)+ VALUE(ATNBSIL)
COMPUTE AWT SIL=VALUE(AWCSIL)+ VALUE(AWBSIL)
COMPUTE APNTSIL=VALUE(ATNTSIL)/VALUE(AWT SIL)*100
COMPUTE SWTSE=SWCK+SWBSE
COMPUTE STNTSE=SWCK*SNCK/100+SWBSE*SNBSE/100
COMPUTE SPNTSE=VALUE(STNTSE)/VALUE(SWTSE)*100
COMPUTE AWTSE=AWCK+AWBSE
COMPUTE ATNTSE=AWCK*ANCK/100+AWBSE*ANBSE/100
COMPUTE APNTSE=VALUE(ATNTSE)/VALUE(AWTSE)*100
COMPUTE SPNCSIL=VALUE(STNCSIL)/VALUE (SWCSIL)*100
COMPUTE APNCSIL=VALUE(ATNCSIL)/VALUE(AWCSIL)*100
COMPUTE SPNBSIL=STNBSIL/SWBSIL*100
COMPUTE STNCK=SWCK*SNCK/100
COMPUTE STNCPL=STNCSIL+SWCR*SNCR/100
COMPUTE SPNCPL=STNCPL/(SWCSIL+SWCR)*100
COMPUTE STNBSE=SWBSE*SNBSE/100
COMPUTE STNBPL=STNBSIL+SWBR*SNBR/100
COMPUTE SPNBPL=STNBPL/(SWBSIL+SWBR)*100
COMPUTE ADSNS=SNS*100
COMPUTE ADANS=ANS*100
COMPUTE ADTNS=TNS*100
COMPUTE ADJNS=JNS*100
COMPUTE STNTPL=VALUE(STNCPL)+VALUE(STNBPL)

```

COMPUTE PROTACK=STACK/STNCSIL

COMPUTE STNBR=SWBR*SNBR/100

COMPUTE ADSTNBR=100*STNBR

COMPUTE WCSIL=10*SWCSIL

RECODE P(1 THRU 12=1)(13 THRU 24=2)(25 THRU 36=3)(37 THRU 48=4)

INTO B

MISSING VALUES STNCSIL TO B(0).

MANOVA SPNCSIL

BY B(1,4) C(1,3) F(1,3)/

PRINT = OMEANS(TABLES(F, C, F BY C, C BY F BY B))/

DESIGN F VS 1, B VS 1, F BY B=1

C VS 2, F BY C VS 2,

B BY C + F BY B BY C=2

FINISH