BIBLIOGRAPHY

GOLINGAB, LANELYN B. MAY 2009. Growth and Yield of Carrot Planted after Lettuce, Garden Pea, Broccoli and Carrot. Benguet State University, La Trinidad, Benguet

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ABSTRACT

The study was conducted at the Balili area, Benguet State University, La Trinidad, Benguet from August 2008 to April 2009 to evaluate the growth and yield of carrot planted after garden pea, romaine lettuce, broccoli and carrot; determine any allelophatic effect between carrot, broccoli, lettuce or carrot followed by carrot and determine the profitability of carrot planted after the other crops.

Planting carrot after romaine lettuce consistently surpassed the growth and yield of carrot that followed after carrot, broccoli and garden pea. In profitability, carrot planted after romaine lettuce obtained 169.70% return on investment or Php1.70 for every peso invested in the production. On the other hand, carrot planted after carrot, broccoli and garden pea had similar growth and yield performance which were greatly reduced compared from those carrot planted after romaine lettuce. In profitability, carrot after carrot obtained 43.44% return on investment or Php0.43 for every peso spent in the production while carrot after broccoli or after garden pea had negative ROI of 15.56% and 31.62%, respectively.

The plant survival showed significantly lower from the carrot planted after garden pea which was confirmed in the controlled study where parts of the plants (garden pea, carrot, romaine lettuce and broccoli) were soaked in water then used to water the planted seeds in seedling trays. Phytotoxicity may have affected the growth and yield of carrot planted after carrot, broccoli and garden pea.

TABLE OF CONTENTS

INTRODUCTION

Succession cropping refers to the planting of two or more crops one after another on the same piece of land. The main objective is to optimize the use of land for better productivity.

Philippines is an agricultural country but at this time, land availability for production is getting smaller. In order to increase profit from crop production, proper cropping system, intensified use of land and efficient labor management become a matter of necessity. Relatively, majority of the people in the Cordillera are engaged in vegetable production but there is a limited area for expansion.

Recent studies showed that the profitability of crop production is determined by cropping system employed by farmers. Although, these systems are influenced by several factors such as environmental, biological, some old practices like relay cropping or succession cropping are common to most farmers. However, such practices are usually done regardless of the compatibilities of the crops being planted.

Moreover, several farmers listening to the radio program of the BSU Extension Services were asking, why carrot has a poor yield when planted after garden pea. It is then a worthwhile endeavor to verify the observation of farmers that planting carrot after garden pea is not good is indeed true.

There had been few studies and limited information regarding the compatibility of crops for succession cropping. Information gathered from this study will help the farmers select crops that are compatible with carrot for increased productivity. This will not benefit the farmers only but also the extension workers, researchers and the following generations who will be involved in vegetable production.

The study was conducted for the following objectives:

1. to evaluate the growth and yield of carrot planted after lettuce, broccoli, garden pea and carrot;

2. to determine any allelophatic effects between lettuce, broccoli, garden pea or carrot followed by carrot; and

3. to determine the profitability of carrot planted after the other crops to be studied.

This study was conducted at Balili area from August 2008 to April 2009.

REVIEW OF LITERATURE

Description of the Crops

Carrot. Carrot is a biennial plant grown for its edible, fleshy root which is usually orange in color, aromatic and sweet. Carrot (*Daucus carota*), a member of Umbelliferae is believed to be found worldwide, either as a cultivated or a weedy, wild plant with long, dry roots. Wild roots which grow to 5 feet high, can be seen along roadsides and other waste areas where they produce flattish clusters (umbles) of small, white flowers. These white flower clusters give the wild carrots common name of Queen Anne's lace (Bayer *et al*., 2002).

Garden pea. Martin and Leonard (1970) described garden peas to be sweeter and more wrinkled than field peas. The pea is annual herbaceous plant with a whitish bloom on the surface. The leaf consists of one to three pairs of leaflets and terminal brached tendril. The pods are about 3 inches long and contain 4 to 9 seeds. Furthermore, most garden peas have white flowers. The blossoms are in a group. Pods are inflated, 4 to 8 centimeter long and varying in shape (Knott and Deanon, 1967).

Additionally, Benton (1970) describe that the stem of the pea plant are hallow and climbing. Leaves are pinnately compound ending in tendrils that enable the plant to climb and with large leafy stipules at their bases. The flowers are butterfly like, white or purple, about 1 inch across; each has nine united stamens and one free stamen.

Lettuce. Lettuce (*Lactuca sativa* L.) is an annual crop of the family Compositae, and is extensively cultivated for its crisp tender leaves used as salad. There are four major botanical varieties of lettuce. The first major variety of lettuce is head or cabbage lettuce (var. capitata) with a dense leafy head similar to that of cabbage. The two forms of head lettuce are the butter head which has a soft waxy leaves, and the crisp head, which has a crispier, more brittle leaves. The second major variety is leafy lettuce (var. Crispa) which has looser, lesser compact leaf heads. The third major variety is the Romain lettuce (var. Longifolia) which has long shoehorn shaped leaves. The fourth major variety is the asparagus lettuce (var. Asparangira) which has a thick edible stems but is rarely grown in the U.S (Collier, 1964).

Broccoli. Broccoli (*Brassica oleraceae,* Italica group), form of cabbage of the mustard family (Brassicae). Broccoli is a fast-growing, upright, branched, annual plant, 600-900 mm (24-35 inches) tall that bears dense clusters of flower buds at the ends of the central axis and the branches. The flavor of broccoli resembles that of cabbage but it is somewhat milder. Fresh broccoli should be dark in color, with firm stalks and compact bud clusters, as a vegetable it is served as raw or cooked (Goulka and Safra, 1997).

Soil and Climatic Requirements

Garden pea. Purseglove (1968) stated that peas require a cool, relatively humid climate with temperature of 55-65^{o}F. Garden pea seldom yield well in tropics below 4,000 ft or when grown in cool weather, as in India, where they are grown as a winter crop. Hot dry weather interferes with pod setting. Peas require a reasonable level of soil fertility and a pH of 5.5 to 6.5. Pea crops cannot tolerate very acid soils or water logging.

Similarly, Chapman and Carter (1976) reported that peas are best adapted to well drained, clay loam soils. They tolerate soil pH range: the optimum pH is 6.5 but moderate acidity (pH as low as 5.5) is tolerated. In some areas, limiting to raise the soil pH to 6.0 maybe necessary for profitable yields.

Pea is cool season crops and thrives best when the weather is cool and when ample moisture is available. The young plant will tolerate considerable cold and light frosts. If the crop is planted late, maturity takes place when the temperature is too high for optimum growth and yield (Ware, 1937).

Lettuce. Lettuce can be grown on many kinds of soils such as clay loams and muck or peat. It reaches its highest development on sandy loams and silt loams, well supplied with organic matter and on good-well-drained much or peat soil. However, ample sunlight, uniformly cool nights and plenty of moisture are essential for well-developed lettuce heads. High temperature leads to inferior quality and tend to encourage the development of the flowering stems rather than the formation of leaf heads. Good soil moisture is another essential factor (McCollum, 1924).

Carrot. Carrot grows on a deep, loose, loamy or clay loam soil. Experiments in Virginia and New York indicated that soil pH of 6.5 gives maximum yield and extremely low yield at 5.2 (Thompson and Kelly, 1959). Similarly, Knott and Deanon (1969) stated that carrot grow best on soil pH ranging from 6.0 to 6.8 in a soil with deep, friable nature free of debris and rocks.

On the other hand, Kinoshita (1972) also cited that carrot requires abundant and well distributed moisture supply. Moroever, Work and Carew (1945) added that inadequate irrigation leads to storage root misshaping, forking or branching with tough texture. Knott and Deanon (1969) explained that on all types of soil, irrigation and adequate rain is necessary to keep the plant grow rapidly and to promote uniform and tender roots up to the harvest time.

Tindal (1983) mentioned that carrot is sensitive to temperature fluctuations. Furthermore, he stated that carrot planted in soils having high temperature encourage the production of short roots. In excess of 28 centigrade, seed germination was severely affected and root produced were pale yellow and fibrous with reduced beta-carotene.

Broccoli. Broccoli grows best in cool weather and in fertile, well-drained, amply watered soil. It can endure light frost. Plants are started under glass and transplanted outdoors for summer harvest, or they are planted directly outdoors for autumn harvest (Bayer *et al*., 2002).

Moreover, Ranson (1998) stated that broccoli grows best at temperature between 10^oC and 25^oC and commercial culture takes place primarily in coastal areas with moderate climates.

Importance of the Crops

Garden pea. Purseglove (1968) mentioned that peas are important garden and field crop throughout the temperate regions, where they are grown for fresh peas and which are also canned for fresh peas and for dry peas. Further, Rachie (1979) reported that legumes are crucial to the balance of nature for many are able to convert nitrogen gas from the air into ammonia, soluble form of nitrogen which is readily utilized by plants.

Additionally, Bawang (2006) reported that garden pea is important crop in Benguet and some area of Mt. Province. In fact, it is one of the top 10 important cash crops of these growing area and is a high-value crop commanding a price per kilo of from Php0.35-Php0.50 or higher during periods of scarcity.

Lettuce. Lettuce is widely cultivated crop and leading vegetable with high market deman. It is considered as one of the most popular crop due to its nutritive value. It contains 95% water and it is a good source of vitamins and minerals (Knott and Deanon, 1967).

Moreover, Bawang (2006) reported that lettuce is one of the major vegetable crops grown in Benguet and in Mt. Province.

Carrot. McCollum and Ware (1975) reported that historically, the carrot was used primarily for medicinal purposes and was not generally used as a food plant until the beginning of the 20th century. Carrots are an excellent source of Vitamin A and a good source of Vitamins B, C and G (B_2).

Moreover, Bawang (2006) mentioned that carrot is the third important crops in the Cordillera Vegetable Industry and some area in the country. It has the highest return on investment (ROI) among the major vegetables in the industry. In addition, it is a heavy toner crop that in terms of land area, it maybe the most beneficial as to the weight of produce per unit area.

Broccoli. Divinagracia (2005) reported that cultivars of *Brassica oleraceae* such as broccoli, cauliflower and cabbage are commercially important vegetable grown in the high elevated areas of Mt. Province, Kanlaoan, Negros Occidental, Cebu and Mindanao. They are also grown in Ilocos region (374 ha in Ilocos Sur, 18 ha in Ilocos Norte).

Moroever, Bawang (2006) stated that broccoli are high-value crops and are priced quite high. During periods of scarcity, a kilo may cost from Php50.00 to as high as Php120.00.

Succession Cropping

Earlier, Thatcher (1923) stated that in succession cropping, the first crops affect the yield of the following crops either beneficial or deleterious. Moreover, Sabarth (1970) stated that a plant may enhance the growth and yield of another by adding nutrients to the soil.

Relatively, Delorit (1959) stated that a well-planned crop rotation conserves, improves and increases the productivity of the soil rather than depleting the fertility over a period of time.

Furthermore, Cevallos (1933) stated that planting of different crops in succession cropping on a piece of land merely prevents the exhaustion of any particular plant food from the soil. He also indicated that when successive crops of one kind are grown on the same area, those lements which are msore consumed become exhausted; hence the land becomes weak and sticky.

Bawang and Victor (1982) found that suitable succession crop after cabbage, white potato and cucumber is carrot. While after bush bean and carrot is white potato and cucumber maybe successioned after cucumber, cabbage, carrot and white potato. In addition, garden pea maybe planted after white potato, garden pea and cabbage. They also found that cropping patterns like carrot-carrot and carrot-Chinese cabbage causes tremendous reduction in yield.

A reduction in both crop yield and quality often occurs when the same crop or its related species are cultivated on the same soil successively. This phenomenon is called soil sickness. It is a complicated natural phenomenon and the causes are not yet fully known. Various factors such as the build up of pests in soil, disorder in physico-chemical properties of soil, autotoxicity (special kind of allelopathy) and other unknown factors are believed to be involved in soil sickness (Narwal, 1999).

Moroever, the author reported that pea is vulnerable to soil sickness and there was 50% decrease in the yield in the second cropping. Furthermore, the residual nutrient solution after culture of pea not only inhibited the growth of pea, but also showed significant phytotoxicity to such crops such as carrot, eggplant, bean and Chinese cabbage.

Autotoxic Substances of Pea

Concerning the autotoxic substances, Hatsuda *et al* (1963) isolated vanillic acid and p-coumaric acid from the water extract of pea root. The phytotoxicity of these compound is well-known.

Similarly, Vaughan and Ord (1991) cultured pea seedlings under a xenic condition and collected root exudates with a XAD-4 resin column. They identified ferulic, vanillic, p-coumaric and p-hydroxy-benzoic acids from 1 fresh weight of roots during a 14-41 culture period were reported to be 5 and .04 mg, respectively. They also found out that greatest phytotoxicity of root exudates appeared just before the beginning of flowering but only a limited amount of phenolic acids such as benzoic acid were detected in the exudates. It was unlikely that phytotoxicity was mainly due to phenolic acids. Phytotoxicity of phenolic acids to pea was greatly modified by the nutrient status of growth medium. In Houghland nutrient solution containing only 10% of its normal nitrate content, 1 um concentration of vanillic, p-hydroxy-benzoic and p-coumaric acids all inhibited growth of roots and greatly modified their morphology. The effects of phenolic acids on protein synthesis in excise root segment and vanillic, p-coumaric and p-hydroxybenzoic acids at .5 mm considerably inhibited protein synthesis.

Takijma and Hayashi (1959) fractioned the residual solution after hydroponic culture of pea into several fractions and found that phytotoxicity in root exudates was mainly due to acidic and neutral substances accumulated in the nutrient solution.

Additionally, Hirayoshi *et al* (1962) found that the phytotoxicity in root exudates was mainly due to acidic substances and at least two phenolic acids were present in the exudates but he failed to identify them.

MATERIALS AND METHODS

Materials

The materials used were carrot seeds (Kuroda Max), lettuce seeds, broccoli seeds, garden pea seeds, watering cans and organic fertilizers such as compost, measuring tools, peg, garden equipment and record book.

Methods

Experimental design and treatments. The experimental layout followed the Randomized Complete Block Design (RCBD) with 3 replications. The treatments were as follows:

Code

T_1 = Romain lettuce-carrot

T_2 = Garden pea-carrot

T_3 = Broccoli-carrot

T_4 = Carrot-carrot

Land preparation. Twelve plots measuring 1m x m5 were prepared for the study. The plots were applied with compost of grasses, cattle and horse manure and sunflower as base dress. No synthetic dry fertilizer was used as the area is under conversion to organic systems of production.

Seedling production. Two hundred Romaine lettuce seeds and broccoli seeds were sown in a seedling trays filled with sterilized soil media. The seedlings were transplanted 3 weeks from emergence. Except the lettuce and broccoli, garden pea seeds and carrot seeds were planted directly to their assigned plots.

Crop maintenance. Irrigation, hilling-up in garden pea and carrot, trellising in garden pea were done on the appropriate schedule and stages.

Data Gathered

The following data were gathered from the various crops:

1. Plant height (cm). The final height of peas was measured from ten sample plants after the last pod harvest and also the lettuce, broccoli and carrot during harvest.

2. Weight of marketable yield (kg). This was the weight of the marketable yield from the first to the last harvest from garden pea, marketable plants from Romaine lettuce and broccoli and the marketable roots of carrot classified as big, medium and small.

3. Non-marketable yield (kg). This was the weight of harvest that was not sold in the market due to damage and malformation.

Planting carrot. Immediately after harvesting the Romaine lettuce, broccoli, garden pea and carrot, the plots were applied with compost and mixed with the soil as fertilizer base dress.

Shallow furrows across the plots at 15 cm distance was made through the use of stick and three seeds of carrot. "Kuroda Max" was dropped at 8 cm spacing then covered with thin soil. In each plot, there were 29 furrows across the plots and seven rows of plants along the plots which means 203 plants per plot.

Irrigation. After planting the seeds, the plots were irrigated and then regularly done twice a week up to the termination of the study.

Thinning. Three weeks after the emergence, the plants were thinned leaving only one plant each hill.

Hilling-up. One month after planting, the plant was hilled-up to cover the base of the plant to avoid exposing the growing roots to sunlight, to cover growing weeds and to fix the plot so that irrigation water will not flow to the canals.

The data gathered, tabulated and subjected to separation test using Duncan's Multiple Range Test (DMRT) were:

1. Leaf length (cm). Ten sample plants were uprooted at random and the leaves were measured from the base of the petiole to the tip of the longest leaves.

2. Number of leaves produced. The leaves of ten sample plants were counted and divided by ten to get the average leaves per plant.

3. Length of roots (cm). Ten sample roots from each plot was measured with Tailor's tape measure from the shoulder of the root to the tip then the average length per root was computed.

4. Weight of big root (kg). This was the weight of big roots harvested per plot following the farmer's practice of classification. Roots measuring 15.0 to 20.0 cm long or weighing 150 g and above was classified as big roots.

5. Weight of medium size roots (kg). Roots that are smaller than the big roots were separated and weighed. Roots measuring 13.0 to 14.9 cm in length or weighing 80 to 149 g was classified as medium roots.

6. Weight of small roots (kg). This was the weight of roots which has smaller than 13.0 cm in length or weighing 40 to 79 g.

7. Weight of "lumpia" (kg). This was the weight of roots per plot that were cracked forked, malformed, very small and with rots.

8. Total yield (kg). This was the weight of all the roots harvested per plot, marketable and non-marketable.

9. Return on investment (ROI). This was taken by using the formula:

$$\text{ROI (\%)} = \frac{\text{Gross Sales} - \text{Total Expenses Per Plot}}{\text{Total Expenses Per Plot}} \times 100$$

10. Percentage germination. After harvesting the first crops, the plant parts were chopped, soaked in water then used for watering the planted seeds of carrot in seedling trays. This was taken using the formula:

$$\text{\% Germination} = \frac{\text{Number of Seeds Germinated}}{\text{Number of Seeds Sown}} \times 100$$

11. Percentage survival. This was taken using the formula:

$$\text{\% Survival} = \frac{\text{Number of Plants Harvested/Plot}}{\text{Number of Plants/Plot (203)}} \times 100$$

12. Percentage of cracked, forked, malformed roots. This was taken using the formula:

$$\text{\% of Cracked, Forked, Malformed Roots} = \frac{\text{Number of Cracked, Forked, Malformed Roots/Plot}}{\text{Total Number of Roots/Plot}} \times 100$$

RESULTS AND DISCUSSION

The First Crops

Table 1 presents the plant heights, marketable and non-marketable yields obtained from the different crops planted on the plots first before the carrot. The data specifically from carrot provided the benchmark for the succession crop, which is carrot.

Leaf Length

Table 2 shows that there were no significant differences in the leaf length of carrots planted immediately after the romaine lettuce, garden pea, broccoli and carrot. This means that the leaf length of carrot was not affected by any of the first crop.

Table 1. Plant height, root length of carrot and the marketable and non-marketable yields from the different crops

CROP	PLANT HEIGHT (cm)	ROOT LENGTH (cm)	MARKETABLE YIELD (kg)	NON-MARKETABLE YIELD (kg)
Broccoli	48.05	-	9.00	0.443
Romaine	25.06	-	4.07	0.564
Garden pea	195.64	-	2.78	0.105
Carrot	65.85	12.30	12.65	6.400

Note: The marketable yield of carrot consists of big roots (7.0 kg), medium-sized roots (3.45 kg) and small-sized roots (2.20 kg).

Table 2. Leaf length (cm) of carrot planted after the different crops

TREATMENT	MEAN
Romaine lettuce – carrot	52.42[a]
Garden pea – carrot	46.21[a]
Broccoli – carrot	42.14[a]
Carrot – carrot	43.01[a]

Means with the same letter are not significantly different at 5% level by DMRT

Number of Leaves Produced

As presented in Table 3, carrot planted after romaine lettuce produced significantly more leaves than those carrot planted after garden pea, broccoli and carrot.

The significantly reduced number of leaves from carrot planted after garden pea, broccoli and carrot may be an allelophatic interaction effect. Bawang and Victor (1982) reported that planting carrot after carrot is not good. On the other hand, planting carrot after garden pea was reported to be affected by garden pea (Narwal, 1999).

Table 3. Number of carrot produced as affected by the first crops

TREATMENT	MEAN
Romaine lettuce – carrot	12.77[a]
Garden pea – carrot	11.50[b]
Broccoli – carrot	10.50[b]
Carrot – carrot	11.13[b]

Means with the same letter are not significantly different at 5% level by DMRT

Length of Roots

As presented in Table 4, carrot planted after romaine lettuce produced significantly longer roots than those carrot planted after garden pea, broccoli and carrot, which have similar root lengths.

The root length of carrot planted during the benchmarking as shown in Table 1 was 12.30 cm which did not differ from the roots of carrot planted after the garden pea, broccoli and carrot. It is however interesting to observe that the carrot when planted after the romaine lettuce produced significantly longer roots. This may imply that the romaine lettuce has no residues and root exudates that will inhibit the growth of roots in carrot, instead enhanced root elongation.

Weight of Big Roots

Table 5 shows the weight of big roots obtained from the succession cropping. Again, planting carrot after Romaine lettuce produced significantly heavier weight of big roots while those that followed after carrot, garden pea and broccoli had similar weight of big roots.

Table 4. Length of roots of carrot planted after the different crops (cm)

TREATMENT	MEAN
Romaine lettuce – carrot	15.08[a]
Garden pea – carrot	13.30[b]
Broccoli – carrot	12.41[b]
Carrot – carrot	12.54[b]

Means with the same letter are not significantly different at 5% level by DMRT

Table 5. Weight of big roots planted after the different crops (kg)

TREATMENT	MEAN
Romaine lettuce – carrot	8.383[a]
Garden pea – carrot	1.554[b]
Broccoli – carrot	0.323[b]
Carrot – carrot	2.417[b]

Means with the same letter are not significantly different at 5% level by DMRT

In the first planting, the weight of big roots was 7.0 kg as presented in Table 1. When carrot was planted after Romaine lettuce, the weight of big roots slightly increased while those followed after carrot, garden pea and broccoli produced tremendously lower big roots. It might be that the significantly more leaves of carrot after Romaine lettuce as presented in Table 3 contributed to the significantly heavier big roots. Moreover, the higher survival of plants following Romaine lettuce (Table 10) might have also contributed to the heavier big roots. Meanwhile, the greatly reduced weight of big roots after garden pea, carrot and broccoli might be an effect of allelopathy as reported by Narwal (1999) and Bawang and Victor (1982).

Weight of Medium Roots

As presented in Table 6, carrot planted after romaine lettuce produced slightly higher weight of medium roots than those carrots planted after garden pea, broccoli and carrot. This result may suggest that medium-sized roots were not affected by romaine lettuce, carrot, broccoli and garden pea.

Table 6. Weight of medium roots of carrot planted after the different crops (kg)

TREATMENT	MEAN
Romaine lettuce – carrot	6.105[a]
Garden pea – carrot	1.613[b]
Broccoli – carrot	2.417[ab]
Carrot – carrot	3.150[ab]

Means with the same letter are not significantly different at 5% level by DMRT

Weight of Small Roots

Table 7 shows the weight of small roots. Statistical analysis revealed slight differences in the weight of small roots when planted after the different crops used in the study. However, carrot planted after garden pea consistently produced the lowest in medium and small roots, which was reported by Narwal (1999) to have allelopathic interaction effect.

Table 7. Weight of small roots

TREATMENT	MEAN
Romaine lettuce – carrot	1.4693[ab]
Garden pea – carrot	0.4367[b]
Broccoli – carrot	2.0750[a]
Carrot – carrot	2.633[a]

Means with the same letter are not significantly different at 5% level by DMRT

Weight of "Lumpia"

No significant differences were obtained from the weight of "lumpia" on roots with some defects such as forking, cracking, rotting and very small (Table 8). This means that all the treatments studied incurred defects in the roots.

Total Yield

Table 9 presents the total yield obtained from carrot planted after Romaine lettuce, garden pea, broccoli and carrot. Statical analysis shows that carrot planted after Romaine lettuce produced significantly higher yield over those planted after carrot, broccoli and garden pea which showed similar total yield.

As shown in Table 1, the total yield of carrot during the first planting was 19.05 kg which was the same when planted after Romaine lettuce, which may imply that there was no phytotoxicity between lettuce and carrot. The significantly reduced yield of carrot when planted after garden pea, broccoli and carrot may indicate an allelopathic interactions between the first and the succeeding crop which is carrot. As was reviewed by Narwal (1999), the residual nutrient solution after culture of pea not only inhibited the

Table 8. Weight of "lumpia" roots of carrot planted after the different crops (kg)

TREATMENT	MEAN
Romaine lettuce – carrot	3.404[a]
Garden pea – carrot	2.658[a]
Broccoli – carrot	1.733[a]
Carrot – carrot	1.553[a]

Means with the same letter are not significantly different at 5% level by DMRT

Table 9. Total yield of carrot planted after the different crops (kg)

TREATMENT	MEAN
Romaine lettuce – carrot	19.181[a]
Garden pea – carrot	6.362[b]
Broccoli – carrot	6.548[b]
Carrot – carrot	9.753[b]

Means with the same letter are not significantly different at 5% level by DMRT

growth of pea, but also showed significant phytotoxicity to such crops as carrot, eggplant, bean and Chinese cabbage.

Percentage Survival

Table 10 presents the percentage of survival of carrot planted after the different crops. Carrot planted after Romaine lettuce obtained the highest percentage survival but did not differ from those planted after carrot and broccoli, all of which significantly

Table 10. Percentage survival of carrot planted after the different crops

TREATMENT	MEAN
Romaine lettuce – carrot	76.52[a]
Garden pea – carrot	32.67[b]
Broccoli – carrot	58.14[a]
Carrot – carrot	67.16[a]

Means with the same letter are not significantly different at 5% level by DMRT

surpassed the survival of carrot planted after garden pea. This observation agree to the report of Narwal (1999) that the residual nutrient solution after culture of pea also showed significant phytotoxicity to carrot.

Percentage Germination

Table 11 shows that there were significant differences among the percentage germination in the controlled experiment where the plant parts were chopped, soaked in water then used for watering the planted seeds in seedling trays.

Obviously, carrot seeds watered with the garden pea solution obtained the lowest percentage of germination which was significantly lower compared to the lettuce and broccoli with similar results which was also significantly lower than those seeds watered with carrot tea solution and those just watered with tap water which have the highest percentage of germination. This result shows reduction of germination from broccoli and Romaine lettuce solution but the lowest was obtained when garden pea solution was used.

Table 11. Percentage germination from controlled experiment (%)

TREATMENT	MEAN
Romaine lettuce – carrot	73.33[b]
Garden pea – carrot	20.33[c]
Broccoli – carrot	78.67[b]
Carrot – carrot	93.67[a]
Control	94.00[a]

Means with the same letter are not significantly different at 5% level by DMRT

Percentage of Cracked, Malformed and Forked Roots

The percentage of cracked, malformed and forked roots is shown in Table 12. Statistical analysis revealed slight differences among the treatments. Carrot planted after garden pea, produced the highest percentage of defects followed by carrot planted after broccoli, carrot and Romaine lettuce had the lowest but did not differ significantly. The lowest percentage of roots with defects from carrot planted after romaine lettuce might have contributed to the consistently higher marketable roots.

Return on Investment

Table 13 shows the profitability of carrot planted after lettuce, garden pea, broccoli and carrot. The main factor that affected the return on investment was the labor cost. The study showed that planting carrot after romaine lettuce obtained 169.70% return on investment or Php1.69 for every peso invested in the production. Planting carrot after carrot obtained 43.44% ROI or Php0.43 for every peso spent in the

Table 12. Percentage of cracked, malformed and forked roots

TREATMENT	MEAN
Romaine lettuce – carrot	18.77^{b}
Garden pea – carrot	50.29^{a}
Broccoli – carrot	41.32^{ab}
Carrot – carrot	30.48^{ab}

Means with the same letter are not significantly different at 5% level by DMRT

Table 13. Return on investment in a 15 sq m plot

ITEM	ROMAINE-CARROT	PEA-CARROT	BROCCOLI-CARROT	CARROT-CARROT
A. Marketable yield	47.872	11.111	14.445	24.600
(kg)	937.81	217.66	282.97	481.91
B. Sales (Php)				
C. Expenses (Php)	21.66	21.66	21.66	21.66
1. Seeds	35.00	35.00	35.00	35.00
2. Compost	291.06	261.66	278.46	279.30
3. Labor				
Total Expenses	347.72	318.32	335.12	335.96
Net Income	590.09	-100.66	-52.15	145.95
ROI (%)	169.70	-31.62	-15.56	43.44

Note: Selling price ranged from Php15.00 to Php30.00 per kilo or an average price of Php19.59

production. Meanwhile, planting carrot after broccoli obtained a negative ROI of 15.56% and planting carrot after garden pea obtained the highest loss of 31.62% or Php0.32 for every peso invested in carrot planted after garden pea.

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary

The study was conducted at Balili area from August 2008 to April 2009 to evaluate the growth and yield of carrot planted after garden pea, lettuce, broccoli and carrot, to determine any allelophatic effect between carrot, broccoli and carrot followed by carrot and to determine the profitability of carrot planted after the other crops studied.

Results show that planting carrot after romaine lettuce produced more leaves, longer roots, heavier big roots, medium-sized roots and higher percentage of plant survival resulting to the heaviest total yield. In most of the data gathered, planting carrot after carrot, broccoli and garden pea showed similar results except the percentage of plant survival wherein carrot planted after carrot closely followed the carrot planted after romaine lettuce. This advantage gave the carrot planted after carrot slightly higher weight of big, medium and small-sized roots. Apparently, carrot planted after garden pea had the lowest percentage of plant survival supported by the controlled study on the percentage of germination.

The economic analysis showed that carrot planted after romaine lettuce obtained the highest net income with a return on investment of 169.70% or Php1.70 return for every peso invested in the production. This was followed by planting carrot after carrot with 43.44% ROI or Php0.43 return for every peso spent in the production. On the other hand, planting carrot after broccoli and garden pea incurred a loss of Php0.16 and Php0.32, respectively, for every peso invested in the production of carrot.

Conclusion

Based on the results presented and discussed, planting carrot on plots previously planted with romaine lettuce seem to enhance growth and yield far better than after carrot while carrot planted after broccoli and garden pea had tremendously reduced growth and yield which resulted to economic loss that might indicate allelophatic interaction.

Recommendation

It is therefore recommended, that carrot should be planted after romaine lettuce to avoid phytotoxicity that will affect growth and yield of carrot. It is also recommended that similar studies on other crops be done to find out compatible succession cropping.

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APPENDICES

Appendix Table 1. Leaf length (cm)

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	50.71	49.62	56.94	157.27	52.42
Garden pea – carrot	48.44	50.01	40.17	138.62	46.21
Broccoli – carrot	43.69	44.61	38.11	126.41	42.14
Carrot – carrot	44.30	38.05	46.67	129.02	43.01

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	4.2704	2.1352			
Treatment	3	195.5234	65.1744	2.66^{ns}	4.76	9.78
Error	6	147.2240	24.5373			
TOTAL	11	347.0178				

^{ns} - Not significant

Coefficient of variation = 10.78%

Appendix Table 2. Number of leaves produced

TREATMENT	REPLICATION			TOTAL	MEAN
	I	II	III		
Lettuce – carrot	13.30	12.30	12.80	38.40	12.80
Garden pea – carrot	11.80	11.00	11.70	34.50	11.50
Broccoli – carrot	11.10	10.00	10.40	31.50	10.50
Carrot – carrot	10.90	10.00	12.50	33.40	11.13

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F	
					0.05	0.01
Block	2	2.5550	1.2775			
Treatment	3	8.2091	2.7363	7.98**	4.76	9.78
Error	6	2.0583	0.3430			
TOTAL	11	12.8225				

** - Highly significant Coefficient of variation = 5.10%

Appendix Table 3. Length of roots (cm)

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	15.77	14.65	14.82	45.24	15.08
Garden pea – carrot	13.54	13.22	13.14	39.90	13.30
Broccoli – carrot	12.73	12.92	11.59	37.24	12.41
Carrot – carrot	13.40	10.86	13.35	37.61	12.53

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	15.4639	0.9324			
Treatment	3	13.5990	38.4589	6.47**	4.76	9.78
Error	6	4.2062	3.2320			
TOTAL	11	19.6702				

** - Highly significant

Coefficient of variation = 6.28%

Appendix Table 4. Weight of big roots (kg)

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	10.350	7.548	7.251	25.149	8.383
Garden pea – carrot	1.400	1.576	1.985	4.961	1.650
Broccoli – carrot	0.500	0.300	0.170	0.97	0.320
Carrot – carrot	6.550	0	0.700	7.25	2.420

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	TABULAR F 0.01
Block	2	12.7748	6.3874			
Treatment	3	115.3767	38.4589	11.90**	4.76	9.78
Error	6	19.3921	3.2320			
TOTAL	11	147.5437				

** = Highly significant

Coefficient of variation = 56.73%

Appendix Table 5. Weight of medium roots (kg)

TREATMENT	REPLICATION			TOTAL	MEAN
	I	II	III		
Lettuce – carrot	6.790	8.775	2.750	18.315	6.105
Garden pea – carrot	0.700	1.650	2.490	4.840	1.610
Broccoli – carrot	4.000	2.750	0.500	7.250	2.420
Carrot – carrot	5.525	1.250	2.675	9.450	3.150

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F	
					0.05	0.01
Block	2	9.7323	4.8661			
Treatment	3	34.5415	11.5138	2.61^{ns}	4.76	9.78
Error	6	26.4937	4.4156			
TOTAL	11	70.7676				

^{ns} = Not significant

Coefficient of variation = 63.2696%

Appendix Table 6. Weight of small roots (kg)

TREATMENT	REPLICATION			TOTAL	MEAN
	I	II	III		
Lettuce – carrot	1.250	1.658	1.500	4.408	1.470
Garden pea – carrot	0.120	0.590	0.600	1.310	0.440
Broccoli – carrot	2.950	2.775	0.500	6.225	2.075
Carrot – carrot	2.350	3.300	2.250	7.900	2.630

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F	
					0.05	0.01
Block	2	1.5088	0.7544			
Treatment	3	7.9770	2.6523	5.08**	4.76	9.78
Error	6	3.1341	0.5223			
TOTAL	11	12.6000				

** = Highly significant

Coefficient of variation = 43.7077%

Appendix Table 7. Weight of “lumpia” (kg)

TREATMENT	REPLICATION			TOTAL	MEAN
	I	II	III		
Lettuce – carrot	1.760	1.950	6.502	10.212	3.404
Garden pea – carrot	1.175	2.900	3.900	7.975	2.660
Broccoli – carrot	2.55	1.850	0.900	5.200	1.730
Carrot – carrot	1.375	1.660	1.625	4.660	1.500

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F	
					0.05	0.01
Block	2	4.8174	2.4087			
Treatment	3	6.6608	2.2202	0.89	4.76	9.78
Error	6	14.9974	2.4995			
TOTAL	11	26.4757				

ns = Not significant Coefficient of variation = 67.64%

Appendix Table 8. Total yield

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	20.150	19.931	18.003	58.084	19.360
Garden pea – carrot	31.395	6.716	8.975	19.086	6.362
Broccoli – carrot	10.000	7.675	1.970	19.645	6.548
Carrot – carrot	15.800	6.210	7.250	29.260	9.750

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	22.8930	11.4465			
Treatment	3	325.9673	108.6557	7.69**	4.76	9.78
Error	6	84.7624	14.1270			
TOTAL	11	433.6228				

** = Highly significant

Coefficient of variation = 35.93%

Appendix Table 9. Percentage survival

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	77.34	75.37	76.85	229.56	76.52
Garden pea – carrot	35.96	46.79	15.27	98.02	32.67
Broccoli – carrot	75.86	66.50	32.02	174.38	58.13
Carrot – carrot	76.85	68.97	55.67	201.49	67.15

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	48.5000	24.2500			
Treatment	3	9192.3333	3060.1111	114.78**	4.76	9.78
Error	6	160.1666	26.6944			
TOTAL	11	9401.0000				

** = Highly significant

Coefficient of variation = 7.7694%

Appendix Table 10. Percentage germination

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	71	84	65	220	73.33
Garden pea – carrot	21	19	21	61	20.33
Broccoli – carrot	81	78	77	236	78.67
Carrot – carrot	96	93	92	281	93.67
Control	88	96	98	282	94.00

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	1129.7180	564.8590			
Treatment	3	3200.6142	1066.8714	9.40**	4.76	9.78
Error	6	680.6783	113.4463			
TOTAL	11	5011.0106				

** = Highly significant

Coefficient of variation = 18.17%

Appendix Table 11. Percentage of cracked, forked, malformed roots

TREATMENT	REPLICATION I	II	III	TOTAL	MEAN
Lettuce – carrot	1.18	16.56	38.56	56.30	18.77
Garden pea – carrot	56.16	46.32	48.39	150.87	50.29
Broccoli – carrot	50.00	37.03	36.92	123.95	41.32
Carrot – carrot	12.82	45.00	33.63	91.45	30.48

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN OF SQUARES	F VALUE	TABULAR F 0.05	0.01
Block	2	180.4455	90.2227			
Treatment	3	1672.2668	557.4222	2.73	4.76	9.78
Error	6	1225.0534	204.1755			
TOTAL	11	3077.7658				

ns = Not significant Coefficient of variation = 40.58%