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# Rotations in Coastal Plains to Combat Desertification in Egypt

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**Abstarct:** Northern coastal plains in west of Alexandria extend towards Libyan borders. The rainfall increases from west of Alexandria to Libyan border (150 ~ 200 mm /y). Degradation and desertification threaten these areas and it is necessary to adopt innovative approaches to the use and management of such fragile resources. The major constraints which threaten sustainability in these areas are the disappearance of crop rotation and the use of cereal mono-cropping particularly barley. Agricultural development and crop intensification project conducted three series of experiments to innovate the cropping systems in these areas. Conventional two year rotations and intensive two year were compared with the mono-cropping system. The data obtained revealed that the yield of crops in any rotation or in mono-cropping pattern were generally higher in 2008 season rather than in 2009 season and was in parallel with the rainfall rate. Barley, lentil and pea were more pertinent in these areas whereas wheat was drastically affected particularly in the second year. In two year rotations yield of cereals (wheat and barley) improved in the second year. In cereal rotations wheat was drastically affected in mono-cropping rather than two year rotations whereas the effect was not pronounced in leguminous crop (lentil and green pea). In intensive crop rotations, the continuation of cropping in summer necessitates one supplementary irrigation, since all plots that were subjected to rain only had perished due to the modest quantities of rainfall. With the supplementary irrigation cantaloupe plants continue growing till fruit set and ripening. Nevertheless, the yield of cantaloupe, after wheat and barley yield was drastically affected rather than after lentil and green pea.

**Key words:**

## INTRODUCTION

Northern-western coastal plains is located in west of Alexandria city. The region extends towards Libyan borders. The rain fall rate increases from west of Alexandria to near Salloom city at the Libian border (150-200 mm /yr). degradation and desertification threaten this region and it is necessary to adopt innovative approaches to the use and management of such fragile resources. There is no crop rotation in this region. This is because the choice of cropping depends on the rain fall amount each year and is not really guided by a fertility maintenance logic, that could be found in the fertile old irrigated lands. Soil type and topography could direct applying crop rotation. On sandy sloping plots watermelon based rotation is expected to be most common. On flat deep sandy loam soil, cereal mono-cropping is the rule. The inclusion of legumes in rotation is not known nor practiced except lentil. Lentil is the only legume crop cultivated in the region in a very small plot (or on research basis). The number of farmers cultivating lentil and the average of farmer share and the total area devoted to lentil are increasing with time but at a very slow rate in spite of researchers and extensionist encouraging [1].

Crop rotation proved positive effect on yield, combat diseases, pests and weeds. Rotations avoid yield depressions index monocropping which increase population microorganisms that are pathogenic and decrease population beneficial microorganisms in crop root rizosphere [2] and reduce production of phytoxic allelopathic chemical and improve physical and chemical conditions of soil [3]. Several investigators studied the effect of crop sequence and crop rotation on crop productivity and soil characteristics [4-10]. They all demonstrated that growing creal crops after legume crops produced more grain yield than those grown after none legume crops. In cereal-legume rotaion, the cereal benefits from the nitrogen fixed by the legume and the decomposition of the nutritive-biomass, root and nodules

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of legume which help the increases of soil organic matters as well as reduces weed population density and biomass production [11-13].

Crop rotation affects soil fertility. Fertility increased with the inclusion of legumes in crop rotation. [14]showed that the available NPK and organic matter were higher in second cycle than that of zero time and the first cycle of the crop rotation Abou Keraisha *et al*. [10] supported these results. Lus and Sun [15]; Lulakis and Pestas [16]; Estefanous *et al*. [17] and Mekki *et al*. [18] showed gradual soil improvement through duration of crop rotation where EC, pH and ESP values decreased and sodium ion exchange with calcium and its acidic media lead to lowering pH values [19]. Efficiency of manure might be due to its copious content of major and minor nutritive elements available to plant root absorption, the acidic effect of manure which lower ph value and encourage also nutrient absorption [17].

Barley crop residues are fed to animals. Since, the animal manure is usually applied to fields, there is a partial restitution of the exported nutrients, but manure is not applied every year which means that a lot is wasted away. In addition to this, not all the fields are manured. Therefore, restitution of nutrients can be considered as marginal. Bedouin farmers are also used to pull out the whole plants at harvest, therefore there is no plant residues remain in the soil [20].

The majority of cereal farmers do not apply manure to their farms, but at very low rates of application. The rapid rural appraisal survey showed that 5% of the farmers use pure manure and only 32% of them are self sufficient of manure. They use manure for their crops particularly fruit trees. However, farmers apply manure to crop only if rain fall is considered good and it is usually confined to the best part of the field.

The use of manure is neither timer wise nor space-wise regular. The majority of farmers (70%) do not use chemical fertilizers, the rest apply fertilizer to fruit trees (15%), crops intercropped under trees (10%) and pure stand crop (5%). They do not use fertilizers mainly due to high costs, high risk related to rainfall and damage to the plant if rain is not adequate. Only farmers close the Sea apply the chemical fertilizer where better chance for rain occurs.

## MATERIALS AND METHODS

Rotation trials were performed in Sidi Barani 850 Km west of Alexandria in 2008 till the end of 2009 year. The studies included comparisons of three types of rotations; mono-cropping rotations, two years crop rotations and intensive crop retains. Lentil, barley, wheat, green pea, cantaloupe and watermelon were selected to rotate in the studied rotation, according to their pertinency to grow in such arid environment. The prevailing rotation in this region is barley based rotation. Mono-cropping barley rotation is the most common rotation. In years with good rainfall, the cultivated area with barley extends to cover most cultivable lands.

The Three Types of the Suggested Rotations Are as Follows

a. Mono-Cropping Rotations:

| Rotation | Components |
|---|---|
| Cereal rotations: | |
| Rot. 1 | Barley / Barley |
| Rot. 2 | Wheat / Wheat |
| Legume rotations: | |
| Rot. 1 | Lentil / Lentil |
| Rot. 2 | Green Pea / Green Pea |

b. Two year rotations:

| Rotation | Components |
|---|---|
| Rot. 1 | Barley / Lentil |
| Rot. 2 | Wheat / Lentil |
| Rot. 3 | Barley / Green Pea |
| Rot. 4 | Wheat / Green Pea |
| Rot. 5 | Lentil / Green Pea |

c. Intensive crop rotations:

| Rotation | Components |
|---|---|
| Rot. 1 | Barley / Cantaloupe / Barley |
| Rot. 2 | Wheat / Cantaloupe / Wheat |
| Rot. 3 | Lentil / Cantaloupe / Lentil |
| Rot. 4 | Green Pea / Cantaloupe / Green Pea |
| Rot. 5 | Lentil / Watermelon / Lentil |

Treatments were assigned in complete randomized block design and were the combinations of the examined crops and fertilization regimes:

- Crop plants received no nitrogen fertilizer or manure.
- Fertilization with mineral nitrogen fertilizer at the recommended rate for each crop.
- Fertilization with sheep manure at the rate of 10 $m^3$ /fed for each crop.
- Half the mineral nitrogen fertilizer (as recommended of each crop) and half the manure rate (5 $m^3$/fed).

Application of manure was carried out before sowing crop (according to the treatment imposed) whereas application of mineral nitrogen was carried out at seedling stage (20 days after germination). Calcium super phosphate was mixed with soil before sowing crops. Treatments were replicated for four times. Plot area was 84 $m^2$.

Application of mineral nitrogen fertilizer was as in the following table:

| | Nitrogen fertilizer as ammonium nitrate (Kg N/fed) | Phosphatic fertilizer as calcium super phosphate |
|---|---|---|
| (Kg $P_2O_5$/fed) | | |
| Barley (Giza 123) | 60 | 15.5 |
| Wheat (Sakha 93) | 75 | 15.5 |
| Green Pea (Master b) | 20 | 15.5 |
| Lentil (Pericose) | 20 | 15.5 |
| Cantaloupe | 50 | 15.5 |
| Watermelon | 60 | 15.5 |

Seeds of different selected winter crops in both mono-cropping rotations and 2 year crop rotations were sown on first of November in 2008 and 2009 seasons and on 5th of November in case of intensive rotations in both seasons (2008 and 2009). Cantaloupe and watermelon in summer seasons in intensive rotation were sown after harvesting winter crops with using deep furrow method and applying one supplementary irrigation in May in both summer seasons.

Harvesting dates of crops are presented in the following table:

| | Mono-cropping system | 2 year crop rotation | Intensive rotation |
|---|---|---|---|
| Barley | 15 April | 10 April | 10 April |
| Wheat | 10 May | 15 May | 8 May |
| Lentil | 20 April | 22 April | 22 April |
| Green Pea | 15 February | 10 February | 20 February |
| Cantaloupe | - | - | 5 August |
| Watermelon | - | - | 10 August |

Rainfall rate in 2008 was higher than in 2009 as in the following table:

Rainfall rate and distribution (mm):

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | September | October | November | December | January | February | March | April | May | June | July | August | Total |
| 2008 | 0 | 0 | 30 | 30 | 50 | 30 | 15 | 5 | 0 | 0 | 0 | 0 | 160 |
| 2009 | 0 | 0 | 25 | 40 | 28 | 15 | 18 | 0 | 0 | 0 | 0 | 0 | 126 |

These rotations were conducted in private farm and were performed on calcareous soil.

**Soil Physical and Chemical Analysis:** Three soil samples at depth 0, 10, 20 and 40 cm were taken representing three plots of each rotation in mono-cropping, two year rotation and intensive rotation. They were mixed and sent to laboratory for physical and chemical analysis before sowing the crops.

After harvesting the crops in the second year soil samples were also taken from each rotation when the crops received half the rate of mineral nitrogen fertilizer and half the rate of sheep manure and sent to laboratory for chemical analysis.

Physical and chemical analysis before sowing crops are presented in the following table:

| | Available nutrients (ppm) | | | pH | EC | ESP | $CaCo_3$ | Clay (%) | Silt (%) | Sand (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | | | | | | | |
| Before sowing | 25.4 | 16.3 | 510 | 8.3 | 0.49 | 17.1 | 51 | 23.1 | 17.4 | 47.8 |

**Statistical Analysis:** The data obtained were statistically analyzed by using computer statistical program MSTAT-C (Freed and Eisensmith, 1986). Fishers analysis of variance technique was employed by [21] and the least significant differences LSD at 0.05 was used to compare the treatment means.

## RESULTS AND DESCUSSION

**Effect of Different Types of Crop Rotation**

**Mono-Cropping rotation:** Data in table 1 indicate clearly that mono-cropping systems in winter season; barley / barley; wheat /wheat as cereal mono-cropping systems or lentil /lentil; green pea /green pea as leguminous mono-cropping systems results in lower yield in the second year. The deleterious effect of following mono-cropping system was more pronounced in cereal rotations as compared with legume rotations. The percent reductions in yields due to follow mono-cropping system of barley or wheat were estimated to 34.01 and 28.67%, respectively. Whereas the reductions when following lentil or green pea mono-cropping were only 15.02 and 17.11% respectively. These results are in agreement with those obtained and

Table 1: Different forms of monocropping rotations (Yield – Kg/fed)

| | | First year | Second year | Reduction (%) |
|---|---|---|---|---|
| Rot. 1 | Barley – Barley | 470 | 310 | 34.01 |
| Rot. 2 | Wheat – Wheat | 167 | 119 | 28.67 |
| Rot. 3 | Lentil – Lentil | 185 | 157 | 15.09 |
| Rot. 4 | Green Pea – Green Pea | 665 | 541 | 17.11 |

Table 2: Different forms of two year rotation (Yield – Kg/fed)

| | | First year | Second year | Reduction (%) |
|---|---|---|---|---|
| Rot. 1 | Barley | 457 | 400 | 12.50 |
| | Lentil | 166 | 150 | 10.36 |
| Rot. 2 | Wheat | 135 | 123 | 8.98 |
| | Lentil | 140 | 126 | 9.85 |
| Rot. 3 | Green Pea | 554 | 533 | 3.68 |
| | Lentil | 170 | 163 | 4.40 |
| Rot. 4 | Barley | 458 | 442 | 3.55 |
| | Green Pea | 565 | 554 | 1.84 |
| Rot. 5 | Wheat | 115 | 108 | 3.39 |
| | Green Pea | 516 | 513 | 0.58 |

Abou Kraisha *et al.* [5]. Barber [3] and and Cook [2] have reported that mono-cropping systems in most occasions result in yield depression as due to the apparent increases of micro-organisms population that are pathogenic, decrease population of beneficial micro-organisms in crop root rhizosphere and increase production of phtoxic allelopathic chemicals and impair physical and chemical conditions of soil. Interpretation for the relatively superiority of more cropping legumes to cereal mono-cropping is feasible since legumes conserve soil fertility, add nitrogen to soil by the nodulating bacteria and deplete less other nutrients [1, 10, 22]. However, popularity of growing barley in mono-cropping system might owe much to the strong desire of Bedouin farmers to grow it for their food and to feed their animals, particularly sheep. This situation, stimulate researchers rotate crops other than cereal with barley in barley based rotation.

**Two Year Crop Rotations:** The data presented in the two year rotations table 2 indicate clearly that these rotations are more diversified, where, the inclusion of legumes in any of the four rotations mitigate the detrimental effects of allelopathy as well as increases soil fertility by fixing nitrogen by the nodulated bacteria.

Several investigators emphasized the positive effect of crop rotation and optimize crop sequence in crop rotations on crop productivity and improve soil characteristics. Shafshak *et al*. [4], Abou Keraisha [5], Arsheal *et al*. [6], Donang and Bilgili [7], Kamel *et al* [22], El-Masry *et al*. [9] and Abou Keraisha *et al*. [10]. They all domenstrated that growing cereal crops after legume produced more grain yield than those grown after non-legume crops. In cerea-legume rotations, the cereal benefits from the nitrogen fixed by legume and the decomposition of the nutritive biomass, roots and nodules of legume which help to increase soil organic matter [11-13]. Nevertheless, the data revealed that the yield of all crops in the five rotations were lower in 2009 season as compared with 2008 season. These reductions are mainly due to the reduction in rainfall rate in 2009 season (126 mm/yr) as compared with a higher rainfall rate in 2008 season (160 mm/yr). The analysis of data revealed also that reduction in barley in first rotation (barley /lentil) was 12.50% but this reduction diminished to only 3.55% in the fourth rotation (barley /green pea) indicating that rotating barley with green pea had more favourable effect on barley yield. Reduction in wheat yield when alternated with green pea was lower than when wheat was alternated with lentil indicating also that rotating wheat with green pea was more favourable rather than with lentil. From another angle of data it is also evident that reduction in lentil yield diminished only to 4.40% when rotate with green pea, indicating the favourable effect when rotating two legume crops in alternative system.

Further, from another part, it is evident the reductions in the yields of cereal crops; barley and wheat were much more evident as compared with reductions in yields of green pea when it was involved in these systems. The data revealed that reduction in yield of green pea when applying the two year rotations reached minimum as compared with the other crops. The results are in agreement with those obtained by Abou Keraisha *et al* [10].

**Intensive Rotations:** To combat desertification and keep the land ever green, it is very necessary to add supplementary irrigation by the end of winter season, since rainfall is very scare. Irrigation water sources come from wells store water from winter rainfall. Applying supplementary irrigation is carried out after approximately ten days to one month from harvesting winter crops.

Barley, wheat, lentil and green pea were followed by cantaloupe or watermelon to grow on soil water conservation from winter season and the supplementary irrigation. The intensive rotation in table 3 indicate that cantaloupe or watermelon in legume based rotation whether lentil or green pea yielded better than cereal based rotation. Further cantaloupe was more compatible

Table 3: Different forms of intensive rotation (Yield – Kg/fed)

| | | First year | | Second year | |
|---|---|---|---|---|---|
| | | Winter | Summer | Winter | Summer |
| Rot. 1 | Barley – Cantaloupe -Barley | 491 | 656 | 418 | 634 |
| Rot. 2 | Wheat – Cantaloupe - Wheat | 117 | 609 | 87 | 604 |
| Rot. 3 | Lentil – Cantaloupe – Lentil | 134 | 743 | 117 | 748 |
| Rot. 4 | Green Pea – Cantaloupe - Green Pea | 607 | 827 | 554 | 902 |
| Rot. 5 | Lentil – watermelon - Lentil | 141 | 788 | 110 | 772 |

Table 4: Different forms of monocropping systems under different sources of nitrogen fertilization (Yield – Kg/fed).

| | Rotation | | | |
|---|---|---|---|---|
| N Fertilization Sources | Rot. 1 Barley – Barley | Rot. 2 Wheat – Wheat | Rot. 3 Lentil – Lentil | Rot. 4 G. Pea – G. Pea |
| | | First year | | |
| Zero | 418 | 122 | 125 | 462 |
| Manure | 480 | 152 | 168 | 692 |
| Nitrogen | 460 | 170 | 203 | 685 |
| M + N | 523 | 225 | 243 | 835 |
| LSD at 0.05% | NS | 14 | 45 | 105 |
| | | Second year | | |
| Zero | 250 | 73 | 75 | 232 |
| Manure | 287 | 105 | 127 | 593 |
| Nitrogen | 335 | 137 | 203 | 610 |
| M + N | 373 | 161 | 223 | 730 |
| LSD at 0.05% | 57 | 38 | 49 | 116 |

with green pea rather than lentil, but was adversely affected when grown with winter wheat. Reductions in the main winter crops (barley, wheat, green pea and lentil) when were grown after cantaloupe followed the same pattern of change as in the two year winter rotation. Greatest reduction was observed when wheat was followed by cantaloupe in summer, followed by wheat (Rot. 2) in the second winter (25.57%). Percent reduction in barley – cantaloupe – barley (Rot. 1) was 14.85% in lentil – cantaloupe – lentil (Rot 3) was 13.04% and in green pea - cantaloupe – lentil (Rot 4) was 8.65% indicating that legume was more favourable in these intensive rotations.

Growing watermelon as a summer crop in intensive rotation resulted in lowest yield of lentil (the main winter crop). On other hands cantaloupe the summer crop which was grown in between lentil or green pea as the main winter crop in (Rot. 3) and (Rot. 4) achieved highest cantaloupe yield and yielded more in the second year, although the rainfall was lower whereas, cantaloupe yielded less in cereal rotation (Rot. 1), (Rot. 2) particularly in second season.

**Effect of Different Sources of Nitrogen Fertilizers on Yield of Cereal and Legume Crops in Different Type of Rotations**

**Mono-Cropping System:** Data analysis indicate that all sources of nitrogen fertilization stimulated both cereal and legume crops grown in mono-cropping system to yield better than both cereal and legume crops left without fertilization (Table 4).

These results hold true in both years and are concordant with those obtained by Kamel *et al*. [22]. The data revealed distinctive responses; yields of legume crops in (Rot. 3 and 4) were more than those of cereal crops. Yields under same respective source of nitrogen fertilizer were higher in case of legume rotations as compared with cereal rotation (Table 4). The data also revealed that wheat mono-cropping were more responsive rather than barley. It seemed that barley was more adaptive to the desert environment as compared with wheat [23]. Green pea had similar higher response to different sources of nitrogen fertilizer as compared with lentil in some cases indicating also that lentil was more

The percent increases in crop yield when crops were grown in mono-cropping system is presented in the following table

| | Over non-fertilized (2008) | | | Over non-fertilized (2009) | | |
|---|---|---|---|---|---|---|
| | Manure | Mineral | Man+Min | Manure | Mineral | Man+Min |
| A. Cereal rotation | | | | | | |
| 1.Barley / barley | 14.8 | 10.1 | 25.1 | 14.8 | 34.0 | 49.2 |
| 2. Wheat / wheat | 24.6 | 39.3 | 84.4 | 43.8 | 87.7 | 120.5 |
| B. Legume rotation | | | | | | |
| 1. Lentil | 34.4 | 62.4 | 94.4 | 69.3 | 170.66 | 197.9 |
| 2. Green pea | 53.7 | 48.27 | 80.74 | 155.6 | 162.0 | 214.65 |

adapted to desert environment. From another part severe responses of legume crops in general to any source of nitrogen fertilizer in this arid environment, might owe much to the very poor microbial activity in soil, which render legume crops depend mainly on external sources of nitrogen rather than nodulated bacteria.

Data on the percent increases in yields of cereal or legume crops involved in mono-cropping system due the added different sources of nitrogen fertilizers (table) indicate an apruptly increases in yield of these crops when plants received sheep manure and mineral fertilizer. However, the percent increases when mineral fertilizer was added only to both cereal and legume crops exceeded those received manure only in the second season. These results are in agreement with those obtained by El-Masry [9] and could be interpreted as the sheep manure is considered slow released fertilizer.

**Two Year Rotation:** Data on two year rotation indicate that both cereal and legume based rotations behaved the same as in mono-cropping system, where, all values of yields under respective source of nitrogen fertilizer was superior to those left unfertilized.

Table 6: Different forms of two year rotation under different sources of nitrogen fertilization (Yield – Kg/fed)

| | | First year | | | | | Second year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O | M | N | M+N | LSD at 0.05% | O | M | N | M+N | LSD at 0.05% |
| Rot. 1 | Barley | 440 | 453 | 458 | 472 | 15.17 | 388 | 395 | 407 | 407 | NS |
| | Lentil | 123 | 153 | 170 | 220 | 26.17 | 102 | 147 | 157 | 193 | 26.59 |
| Rot. 2 | Wheat | 97 | 118 | 148 | 175 | 35.28 | 92 | 110 | 148 | 173 | 46.74 |
| | Lentil | 80 | 120 | 160 | 198 | 27.05 | 70 | 125 | 153 | 158 | 46.97 |
| Rot. 3 | Green Pea | 453 | 497 | 553 | 742 | 117.40 | 268 | 467 | 582 | 817 | 176.90 |
| | Lentil | 127 | 163 | 185 | 207 | 17.22 | 122 | 157 | 173 | 202 | 27.66 |
| Rot. 4 | Barley | 437 | 438 | 467 | 478 | NS | 435 | 417 | 427 | 488 | NS |
| | Green Pea | 398 | 478 | 660 | 722 | 70.50 | 332 | 490 | 690 | 705 | 87.80 |
| Rot. 5 | Wheat | 63 | 110 | 125 | 162 | 7.45 | 42 | 102 | 123 | 163 | 20.25 |
| | Green Pea | 303 | 485 | 593 | 682 | 31.81 | 258 | 570 | 580 | 643 | 101.60 |

Percent increases in yields of crops grown in two year rotations:

| | | Over non-fertilized (2008) | | | Over non-fertilized (2009) | | |
|---|---|---|---|---|---|---|---|
| Rotations | | Manure | Mineral | Man+Min | Manure | Mineral | Man+Min |
| Rot. 1 | Barley | 2.95 | 4.09 | 7.27 | 1.80 | 4.96 | 4.90 |
| | Lentil | 44.89 | 53.92 | 89.22 | 24.39 | 38.71 | 78.86 |
| Rot. 2 | Wheat | 21.65 | 52.58 | 80.41 | 19.56 | 60.78 | 88.04 |
| | Lentil | 50.00 | 100.00 | 147.50 | 78.57 | 118.57 | 111.43 |
| Rot. 3 | Green Pea | 9.71 | 22.08 | 63.80 | 74.25 | 124.63 | 204.85 |
| | Lentil | 28.35 | 45.67 | 62.99 | 28.69 | 41.80 | 65.57 |
| Rot. 4 | Barley | 0.23 | 6.86 | 9.38 | - | - | - |
| | Green Pea | 15.08 | 73.18 | 81.40 | 47.59 | 107.83 | 112.45 |
| Rot. 5 | Wheat | 74.60 | 98.41 | 157.14 | 142.86 | 192.86 | 228.00 |
| | Green Pea | 60.67 | 95.71 | 125.08 | 120.95 | 124.81 | 149.22 |

Table 7: Different forms of intensive rotation under different sources of nitrogen fertilization (Yield – Kg/fed)

| | | First year | | | | | Second year | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O | M | N | M+N | LSD at 0.05% | O | M | N | M+N | LSD at 0.05% |
| Rot. 1 | Barley | 435 | 475 | 515 | 538 | NS | 345 | 367 | 468 | 491 | 63 |
| | Cantaloupe | 345 | 708 | 740 | 832 | 102 | 350 | 657 | 763 | 820 | 131 |
| Rot. 2 | Wheat | 60 | 112 | 130 | 167 | 28 | 43 | 73 | 107 | 123 | 20 |
| | Cantaloupe | 315 | 650 | 692 | 780 | 83 | 333 | 697 | 672 | 835 | 157 |
| Rot. 3 | Lentil | 92 | 115 | 148 | 182 | 24 | 72 | 127 | 135 | 133 | 39 |
| | Cantaloupe | 500 | 718 | 825 | 930 | 166 | 517 | 700 | 782 | 912 | 151 |
| Rot. 4 | Green Pea | 443 | 550 | 633 | 800 | 78 | 383 | 503 | 583 | 747 | 156 |
| | Cantaloupe | 593 | 893 | 1027 | 1127 | 277 | 577 | 857 | 1038 | 1140 | 86 |
| Rot. 5 | Lentil | 83 | 140 | 158 | 182 | 21 | 65 | 97 | 110 | 168 | 79 |
| | Watermelon | 367 | 840 | 843 | 1103 | 244 | 428 | 723 | 833 | 1103 | 159 |

The percent increases in cereal were remarkably lower than that of legume in both years in all rotations where cereal crops were alternated with legume crops. Further, it is evident that the response of barley to different sources of nitrogen was not appreciable even when alternated with lentil or green pea. The response of either cereal or legumes to different sources of nitrogen fertilizer was regular. The effect of mineral fertilizer was more pronounced as compared with manure fertilization. Crops grown in two year rotation which received split up dose of manure + mineral fertilizer were associated with highest yields. It seemed also that legume crops when rotate render rebalance major and minor elements which retain soil sustainability. Swarup *et al*. [19], El-Masry *et al* [9] and Kamel *et al*. [22] came to similar results.

**Intensive Rotation:** Data in Table (7) indicate clearly that there general increases when addition of different sources of nitrogen fertilization. These observations hold true in any intensive rotation. There were increases in yield of cereal, legume or the vegetable crops.

The percent increases in yields of crops grown in intensive rotation indicate that (a) percent increases in yield were remarkably higher in legume rotation than in case of cereal rotation (b) the percent increases in cantaloupe (the summer crop) was higher in intensive legume rotation (c) watermelon as the summer crop in intensive rotation was more responsive to any source of nitrogen fertilization rather than cantaloupe. On other part, the data revealed that crops in intensive rotations were less responsive to manuring as compared with mineral fertilization. This observation might owe much to slow release and disintegration of sheep manure as compared with mineral fertilization Swarup *et al*. [19] and Kamel *et al*. [22] came to similar conclusion.

Percent increases in yields of crops grown in intensive rotations:

| | | Over non-fertilized (2008) | | | Over non-fertilized (2009) | | |
|---|---|---|---|---|---|---|---|
| Rotations | | Manure | Mineral | Man+Min | Manure | Mineral | Man+Min |
| Rot. 1 | Barley | 9.20 | 18.39 | 22.30 | 8.98 | 35.65 | 42.32 |
| | Cantaloupe | 105.22 | 114.49 | 141.16 | 134.29 | 10.86 | 87.71 |
| Rot. 2 | Wheat | 86.67 | 116.67 | 178.33 | 69.77 | 148.83 | 186.05 |
| | Cantaloupe | 106.33 | 119.68 | 147.62 | 109.31 | 101.80 | 150.75 |
| Rot. 3 | Lentil | 25.00 | 60.87 | 97.83 | 67.39 | 87.50 | 168.06 |
| | Cantaloupe | 43.60 | 65.00 | 86.00 | 35.40 | 51.26 | 76.40 |
| Rot. 4 | Green Pea | 24.15 | 42.89 | 80.59 | 31.56 | 52.22 | 95.04 |
| | Cantaloupe | 50.59 | 73.19 | 90.05 | 48.53 | 39.90 | 97.57 |
| Rot. 5 | Lentil | 68.67 | 90.36 | 119.28 | 49.23 | 69.23 | 158.46 |
| | Watermelon | 128.88 | 129.70 | 200.54 | 75.41 | 196.31 | 241.39 |

Table 8: Physical and chemical analysis of different types of rotation (before initiation and at the end of rotation cycles)

| Rotations | Time of sampling | Nutritive element (ppm) N | P | K | pH | EC | ESP |
|---|---|---|---|---|---|---|---|
| 1. Mono-cropping rotation: | | | | | | | |
| Rot. 1 (barley /barley) | Before | 24.3 | 17.2 | 520 | 8.0 | 0.50 | 18.2 |
| | After | 15.4 | 15.0 | 485 | 7.8 | 0.47 | 17.1 |
| Rot. 2 (wheat / wheat) | Before | 25.6 | 17.3 | 520 | 8.3 | 0.49 | 18.4 |
| | After | 13.7 | 17.6 | 470 | 7.9 | 0.48 | 16.9 |
| Rot. 3 (lentil / lentil) | Before | 25.3 | 16.9 | 530 | 8.3 | 0.49 | 18.6 |
| | After | 40.4 | 14.3 | 430 | 7.6 | 0.40 | 15.3 |
| Rot. 4 (g. pea / g. pea) | Before | 26.1 | 17.3 | 530 | 8.2 | 0.48 | 18.3 |
| | After | 39.3 | 18.4 | 540 | 7.5 | 0.48 | 16.8 |
| 2. Two-year rotation: | | | | | | | |
| Rot. 1 (barley / lentil) | Before | 24.4 | 17.3 | 525 | 8.0 | 0.50 | 18.3 |
| | After | 48.5 | 16.2 | 500 | 7.4 | 0.44 | 17.2 |
| Rot. 2 (wheat / lentil) | Before | 25.1 | 16.3 | 530 | 8.3 | 0.51 | 18.3 |
| | After | 43.4 | 16.1 | 480 | 7.5 | 0.43 | 16.9 |
| Rot. 3 (barley / g. pea) | Before | 24.9 | 16.3 | 530 | 8.1 | 0.49 | 18.5 |
| | After | 44.6 | 15.8 | 490 | 7.7 | 0.44 | 17.8 |
| Rot. 4 (wheat / g. pea) | Before | 24.8 | 17.4 | 535 | 8.3 | 0.51 | 18.4 |
| | After | 43.4 | 15.6 | 498 | 7.9 | 0.46 | 17.6 |
| Rot. 5 (lentil / g. pea) | Before | 25.2 | 18.3 | 545 | 8.4 | 0.51 | 18.7 |
| | After | 50.4 | 19.3 | 561 | 7.6 | 0.40 | 16.1 |
| 3. Intensive rotation: | | | | | | | |
| Rot. 1 (barley / cantaloupe / barley) | Before | 25.4 | 18.3 | 635 | 8.0 | 0.53 | 18.5 |
| | After | 13.4 | 14.3 | 625 | 7.8 | 0.49 | 16.8 |
| Rot. 2 (wheat / cantaloupe / wheat) | Before | 24.8 | 17.3 | 544 | 8.3 | 0.52 | 18.8 |
| | After | 12.4 | 15.3 | 530 | 7.2 | 0.48 | 16.7 |
| Rot. 3 (lentil / cantaloupe / lentil) | Before | 25.3 | 17.8 | 520 | 8.0 | 0.49 | 16.8 |
| | After | 33.6 | 16.3 | 490 | 7.5 | 0.41 | 16.5 |
| Rot. 4 (g. pea / cantaloupe / g. pea) | Before | 25.3 | 17.4 | 540 | 8.1 | 0.47 | 18.4 |
| | After | 30.6 | 16.3 | 490 | 7.3 | 0.47 | 16.2 |
| Rot. 5 (lentil / watermelon / lentil) | Before | 26.4 | 17.8 | 530 | 8.2 | 0.48 | 18.3 |
| | After | 36.4 | 18.3 | 540 | 7.8 | 0.47 | 16.1 |

**Effect of Different Crop Rotation Systems on Physical and Chemical Properties of the Soil**

**Mono-Cropping Rotation:** Nitrogen, phosphorus and potassium contents in cereal rotation in mono-cropping system (barley /barley) and (wheat /wheat) were lower than those recorded for leguminous rotations (lentil /lentil) and (green pea /green pea) in mono-cropping system (table, 8). While the values of these nutritive elements diminished after harvest cereal crops in cereal rotation, these values of nutrient elements increased in (green pea /green pea) rotation. These results might owe much to more uptake and depletion of these nutrients by the exhaustive cereal plants in cereal rotation whereas, the increase in nitrogen fixation as due to the action of nodulated bacteria, in addition to the appreciable accumulated quantities of phosphorus and potassium when green pea residues disintegrate. These results were in accordance with those obtained by Hussein *et al*. [1] and Kamel *et al*. [22] and Abou Keraisha *et al*. [10].

On other part, data evidenced that physical properties of the soil improved when crops were cultivated whether in cereal or legume rotations. Values of pH, EC and ESP after harvest were evidently lower than those determined before cropping. These observations might be due to plant residues decay and disintegration, releasing several organic acids and other acidic compounds which lower pH and decrease EC and ESP. These results were in accordance with those obtained by Abd El-Hadi *et al*. [14] and Abou Keraisha *et al*. [10]. Swarup *et al*. [19] demonstrated soil improvement through duration of crop rotation, while EC, pH and ESP values decreased. Sodium ion exchange with calcium at its acidic media leads to lowering all these properties.

**Two Year Rotation:** Reciprocal trend of cereal with legumes in two years rotation mitigate the exhaustive effect of cereal on soil properties. When the cereal was followed by legume crops, all values of soil nitrogen

Table 9: Soil content of major nutritive element before initiation and after harvesting in different types of crop rotations as affected by source of nitrogen fertilization

| | | N sources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Zero fert. | | | Manure fert. | | | Mineral fert. | | | ½ manure + ½ mineral fert. | | |
| Rotation type | Time of sampling | N | P | K | N | P | K | N | P | K | N | P | K |
| 1. Mono-cropping rotation: | | | | | | | | | | | | | |
| Rot. 1 (barley /barley) | Before | 20.5 | 15.4 | 480 | 22.4 | 16.3 | 500 | 25.3 | 18.1 | 520 | 25.0 | 19.0 | 580 |
| | After | 13.2 | 13.1 | 380 | 15.2 | 15.3 | 470 | 16.3 | 15.6 | 495 | 16.9 | 16.2 | 595 |
| Rot. 2 (lentil / lentil) | Before | 18.9 | 14.3 | 470 | 23.4 | 15.6 | 480 | 26.8 | 16.8 | 500 | 22.1 | 20.9 | 570 |
| | After | 20.3 | 14.4 | 520 | 24.5 | 15.4 | 525 | 27.3 | 17.3 | 541 | 29.1 | 22.5 | 534 |
| 2. Two-year rotation: | | | | | | | | | | | | | |
| Rot. 1 (barley / lentil) | Before | 19.3 | 13.5 | 445 | 22.6 | 14.3 | 425 | 26.2 | 15.5 | 485 | 19.6 | 18.4 | 485 |
| | After | 20.3 | 14.8 | 485 | 23.4 | 15.8 | 460 | 26.2 | 17.4 | 650 | 29.7 | 20.7 | 605 |
| Rot. 2 (lentil / g. pea) | Before | 18.7 | 14.2 | 475 | 21.7 | 13.7 | 425 | 22.3 | 16.5 | 505 | 22.5 | 17.3 | 440 |
| | After | 22.6 | 16.3 | 510 | 24.7 | 17.4 | 540 | 25.0 | 19.0 | 560 | 28.5 | 20.5 | 570 |
| 3. Intensive rotation: | | | | | | | | | | | | | |
| Rot. 1 (barley / cantaloupe / barley) | Before | 24.6 | 17.3 | 575 | 25.4 | 18.3 | 580 | 27.5 | 19.5 | 640 | 28.5 | 22.3 | 660 |
| | After | 23.6 | 16.2 | 550 | 24.8 | 17.4 | 590 | 26.2 | 18.6 | 630 | 27.0 | 21.0 | 650 |
| Rot. 3 (lentil / cantaloupe / lentil) | Before | 17.4 | 17.8 | 460 | 22.4 | 15.5 | 490 | 28.7 | 18.5 | 560 | 28.4 | 19.2 | 530 |
| | After | 20.3 | 15.8 | 490 | 24.6 | 16.8 | 500 | 26.3 | 17.3 | 545 | 30.0 | 21.3 | 545 |

increased than nitrogen values recorded before rotation initiation. It is evident also that soil nitrogen contents reached maximum in strait 2-year legume rotation (lentil /green pea). Phosphorus and potassium contents in soil when cereal-legume of two year rotations were applied were lower than when soil was analyzed before rotation initiation, except when straight legume rotation (legume /legume) was applied. These observations might be due to the severe effect of growing cereals in these rotations. The data also revealed that the effects of two year rotations on physical properties were regular. All values of these properties declined after the end of rotation cycles rather than at rotation initiation, reached minimals due to the acidic effect of plant residue disintegration. Similar results were also observed in the straight legume 2-year rotations.

**Intensive Rotation:** In straight cereal rotation in intensive system and mediated by cantaloupe in summer (barley / cantaloupe /barley) and (wheat / cantaloupe /wheat), major nutritive elements, N, P and K contents of soil decreased as compared with the values of these contents before rotation initiation. Interpretation is feasible, since both cereal crops and cantaloupe as a vegetable depleted more quantities of these elements. Physical properties declined also after the end of rotation cycles. On the contrary in case of cereal-legume rotation in intensive form, the values of major nutritive elements in soil after harvesting the second crop exceeded those determined at crop rotation initiation in most traits. Physical properties declined also as due to cropping the bare land and plant residue disintegration. The effect of legume-cereal rotation to improve soil physical and chemical characteristics was reported by Luo and Sun [15], Lulakis and Postas [16], Mekki *et al*. [18] and Abou Keraisha *et al* [10].

**Major Nutrient Contents in Soil as Influenced by Different Types of Crop Rotation**

**Mono-Cropping Rotation:** In mono-cropping rotation when cereal rotation (barley /barley) was applied, major nutrients declined as compared rotation mitigation (Table, 9). On other hand, within same type of rotation (mono-cropping) major nutrient contents in legume rotation at the end of rotation cycles exceeded the values recorded at rotation initiation. These results were fairly true under different sources of nitrogen fertilizer. There were increases in these values when manure was applied as compared with non-fertilized rotations in mono-cropping systems. Rotations received mineral fertilizer exceeded those received manure only and those received manure + mineral fertilizer in equal split dose was higher than those received any source of nitrogen fertilization.

**Two Year Rotation:** When 2-year rotations were applied, all major nutritive values were higher at the end of rotation cycles rather than at rotation initiation. Addition of different sources of nitrogen fertilizer followed the same trend as in mono-cropping systems.

**Intensive Rotation:** In intensive rotations, straight barley rotation mediated by cantaloupe showed relatively exhaustion when determining the major nutritive element and showed lower values after rotation cycles as compared with rotation initiations, whereas, the reverse was true when strait intensive legume based rotation was applied. Response of rotations in intensive type followed the same pattern of change. It is also evident that the split dose of manure + mineral fertilizers resulted in best improvement to soil properties and conserve soil sustainability.

To achieve sustainable agriculture in these arid environment as well as soil sustainability, combat degradation and desertification (a) It is necessary to follow up two year rotation (b) Legume crops are very necessary in these rotation to conserve soil sustainability (c) Intensive rotation is also recommended with one supplementary irrigation (d) Split up dose of nitrogen fertilizer is optimum in these areas.

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