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Nutrient cycling and nutrient-use efficiency in an agroecosystem of *Trifolium alexandrinum* L.

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Key words: Phytomass partitioning, Primary productivity, Nutrient accumulation, Organic constituents.

Abstract

Trifolium alexandrinum L. is an essential green forage crop and anti-diabetic medicinal plant in Egypt. The total forage phytomass was about14.3 tons/fed/year. The present study evaluates the dry matter production, nutrient cycling and nutrient use efficiency (NTUE) in an agroecosystem of *T. alexandrinum* under normal agricultural practices and rotational clipping by farmers. The net above ground primary productivity was estimated at about 0.066 and 0.093g/g dry weight/day during the first and last at three growth periods. The rate of nutrient accumulation in shoots was initially greater than the rate of biomass accumulation. There was a gradient of N and K concentration from a minimum in roots and a maximum in shoots which is associated with active translocation of these elements to the shoot. The amount translocated exceeds about 90% of the total uptake of N and K. The total organic constituents (TAC, CP, EE and SOC) in shoot attained their maximum content in the vast growth period. Furthermore, *T. alexandrinum* was found to be having differently for NTUE in the different growth periods. The main controlling factor in changes in NTUE for most elements was due to biomass allocation.

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Introduction

Berseem (*Trifolium alexandrinum* L.) is one of the most important leguminous forages in the Mediterranean region and in the Middle-East. It is one of the most important green fodder plants in Egypt (Pecetti *et al.*, 2012). Despite of the fact that clovers have been known for many centuries as important forage plants and valuable herbs in folk medicine, their chemical characteristics and biological activity remain only partly established (Kolodziejczyk-Czepasn, 2012). Berseem is an annual, sparsely hairy, erect forage legume, 30 to 80 cm high (Hackney *et al.*, 2007). Berseem is a fast growing, high quality forage that is mainly cut and fed as green chopped forage. It is often compared to alfalfa, due to its comparable feed value. However, unlike alfalfa, it has never been reported to cause bloat. It is slightly less drought-resistant but does better on high moisture and alkaline soils. Moreover, berseem can be sown in early autumn and can thus provide feed before and during the colder months (Suttie, 1999). It is very productive when temperatures rise after winter. The seeds are abundant under favorable conditions. Berseem can also be made into silage with oats or be fed chaffed and mixed with chopped straw. Grazing is possible though less common than cutting. Berseem clover can also be used as green manure crop (Hannaway and Larson, 2004).

Climate change presents many challenges to improvements in nutrient use efficiency (NTUE) by its direct effects on the growth and yield of plants, and hence on nutrient demand, and by its influence on soil nutrient cycling, nutrient availability, and uptake. Notwithstanding the uncertainty of the effects of climate change on soil nutrient availability and plant nutrient uptake, improvements in NTUE will be required to sustain productivity into the future (Handmer *et al.*, 2012).

These challenges have brought the importance of plant nutrition to sustainable agricultural production into sharp focus and have highlighted the need to improve NTUE. The higher yields that will be required to maintain (or improve) food security will require increased uptake of most of the essential nutrients at a time when shortages of some fertilizers are being predicted (Cordell *et al.*, 2009). Nutrient concentration and uptake as well as NTUE are the major components of ecosystem nutrient cycles (Gibson *et al.*, 2015). These processes are of ecological importance and may have great influence upon crop production in agro-ecosystems (Madan *et al.,* 2004). Therefore, it is important to know how in total nutrient uptake and nutrient use efficiency is controlled if we are to understand how and why biogeochemical cycles vary within agro-ecosystems.

Materials and methods

Study area

The site of the study is located in El-Behira district, in the Nile Delta about 89km south east of Alexandria and 35km North West of El-Tahrir province, Egypt. The study was carried out in a fallow field of about 5 feddans after the preceding crop (*Zea mays*) was removed and the soil was prepared for the next crop (*T. alexandrinum*) cultivation.

Sampling of plant materials and agricultural practices

The growth duration period was about 228 days. The seeds were sown in mid-October and the last growth was harvested at the end of May. Samples of plant material and soil were collected from 20 randomly located, 30x30cm plots. The short term harvest method of WHO (2003) was applied in sampling plant material. The samples were collected every 15 days in the first, second, third and sixth growth periods, and every 10 days in the fourth and fifth growth periods. Each of the first, second and third growth periods mature within 45 days while 30 days was enough for the last three growth periods.

The phosphorus fertilizer was applied once after fifteen days from sowing at the rate of about 50kg/ feddans. The nitrogen fertilizer was applied three times in the form of urea; the first was associated with the phosphorus fertilizer while the second and third times were after clipping the crop of the first and second growth periods, respectively.

Preparation of plant samples for chemical analysis

The plant samples were separated into different organs, washed carefully with tap water followed by three times with distilled water. The samples were then oven-dried to constant weight at 65°C. The plant and soil samples were analyzed for their contents of nutrients according to Allen *et al.* (1984). Carbohydrates (TAC) were determined by the procedure of Murata *et al.* (1968). Crude protein (CP) was calculated from the estimates of nitrogen content. The content of ether extract (EE) was determined by the Soxhlet extraction method and the structural organic components (SOC) by using the equation described by Le Houerou (1980) as follows:

SOC = 100 - (TAC + CP + EE + ash)

With values substituted as percentages.

Calculation of nutrient use efficiency

The nutrient use efficiency (NTUE) during any time interval was assessed by dividing the plant biomass by the mineral mass calculated from the nutrient content in the material removed by clipping, and that retained by roots during that interval (Shaver and Melillo, 1984).

Soil analysis

Two soil samples were collected for analysis from a freshly exposed surface at the zone of active absorbing roots in each plot. All procedures followed in estimating the soil physical and chemical characters were outlined by Allen *et al.* (1984).

Results

Soil Characteristics

Some physical and chemical features of soil in the study area are listed in Table 1a and 1b. The soil was clayey, neutral (pH 7.1), with water holding capacity of 51.17%, hygroscopic moisture of 0.712% and content of total organic matter of 7.35% and total N ranged from 1.1 to 1.8mg/g.

Table 1b. Some chemical characteristics of soil underneath *Trifolium alexandrinum*.

Date	Total organic matter (%)	pH	Conductivity (mmhos/cm)	HCO_3 (ppm)	Total N mg/g	P	K^+	Na^+ mg/g	Ca^{++}	Mg^{++}
January	7.46	7.0	0.865	0.488	1.8	0.0044	0.009	0.110	0.080	0.036
April	7.25	7.2	0.995	0.366	1.1	0.0014	0.008	0.091	0.060	0.036

Table 1a. Some physical characteristics of soil underneath *Trifolium alexandrinum*.

Date	Sand	Silt (%)	Clay	Water holding capacity (%)	Hygroscopic moisture (%)	Bulk density (g/cm^3)	Porosity (%)
January	39.4	49.8	10.8	52.62	0.702	1.35	16.00
April	40.0	50.0	10.0	49.73	0.722	1.39	13.47

Phytomass and Net Productivity

The rotational clipping regime was distinguished into six characteristic growth periods (Table 2 and Fig. 1). Each of the first second and third periods was about 45 days long, the first from mid-October till the end of November, the second from first of December to mid-January and the third from mid-January till the end of February. The maximum phytomass attained at the end of each period was 308.88, 513.55 and 466.59g/m^2 respectively. The shoots (leaves and stems) shared about 92%, 73% and 65% respectively of that maximum, and the remaining percentage was shared by roots. Each of the fourth, fifth, and sixth growth periods was about 30 days long from the first of March, April and May respectively. The maximum phytomass attained at the end of each period was about 862.44, 1006.89 and 1328.72g/m^2 respectively. The proportional allocation of that maximum to the different organs was about 75%, 73%, and 65% respectively for the shoot about 25%, 22%, and 20% respectively for the root and about 0, 5%, and 15% respectively for the reproductive organs.

The root: shoot ratio attained its maximum (mean = 0.663) during the third growth period (January-February). After that the ratio fluctuated around 0.40 during the last three periods.

The total phytomass accumulation (3393.5g/m²/ year) which is the peak of annual phytomass content of leaves, stems and reproductive organs is provided in Fig. 2. About 27.9% of that total was attained during the first 136 days after sowing (first, second, and third growth periods). The remainder (about 72.1%) was attained during the last 92 days (fourth, fifth, and sixth growth periods).

Table 2. Variations in phytomass (g/m²) ± SD of different organs of *Trifolium alexandrinum*.

Month	Organ				Total	Root/Shoot
	Day	Shoot	Root	Reproductive organs		
Growth period I						
October	30	100.93±1.4	6.72± 1.3	-	107.65	0.066
	15	194.37± 1.8	17.45± 1.5	-	211.82	0.089
November	30	282.22± 4.7	26.66± 3.4	-	308.88	0.094
Growth period II						
December	15	218.51± 5.7	75.92± 6.0	-	294.43	0.347
	31	297.74± 3.7	111.11± 10.0	-	408.85	0.373
January	15	372.22± 4.4	141.33± 8.0	-	513.55	0.379
Growth period III						
January	31	199.25± 5.3	151.14± 4.2	-	350.39	0.758
February	15	257.40± 3.3	164.24± 9.7	-	421.64	0.638
	28	292.59± 4.0	174.00± 8.0	-	466.59	0.594
Growth period IV						
	10	359.25± 5.4	188.18± 6.1	-	547.43	0.523
March	20	598.14± 6.4	200.40± 11.0	-	798.54	0.335
	31	650.22± 3.6	212.22± 10.0	-	862.44	0.326
Growth period V						
	10	453.7±4.5	222.72± 4.4	-	676.42	0.490
April	20	566.66± 3.2	240.34± 9.4	-	807.00	0.424
	30	696.28± 5.9	266.17± 7.5	44.44	1006.89	0.382
Growth period VI						
May	15	444.44± 9.4	270.00± 6.7	105.00	819.44	0.607
	31	855.55± 11.6	273.17± 8.4	200.00	1328.72	0.319

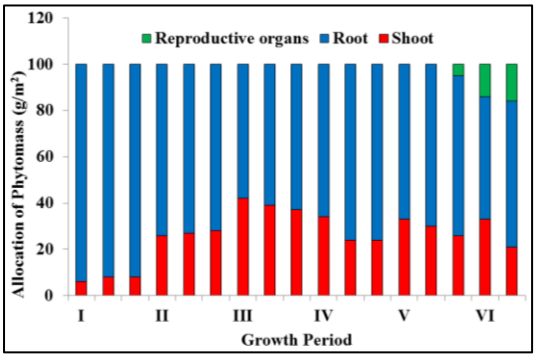

Fig. 1. The proportional allocation of phytomass (g/m²) to different organs of *Trifolium alexandrinum*.

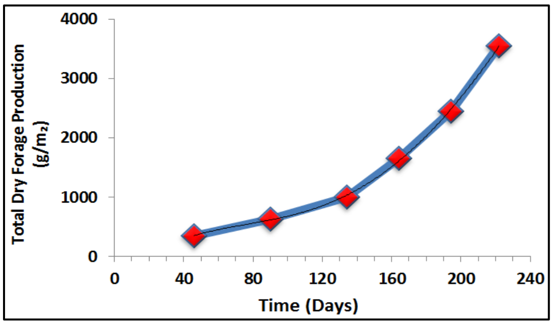

Fig. 2. Temporal variations in the total dry forage production of *Trifolium alexandrinum*.

The net primary productivity (the rate of building up of dry matter per unit weight per unit time) was calculated for both the shoot and root systems during the six growth periods (Fig. 3). In all the growth periods, the maximum net primary productivity of shoots occurred 10 to 15 days after starting the growth of each period. The first and fourth growth period started with high values (about 0.066 and 0.10g/g/day respectively) and declined gradually with the increase in phytomass. As the phytomass built up, the net primary productivity declined sharply (about 0.03 and 0.009g/g/day respectively) when the phytomass was about 309.0 and 862.0g/m² respectively. The net primary productivity exhibited a characteristic trend during the second, third, and fifth periods; a sharp decline from a maximum at the start of growth, then a gradual decrease with the increase in phytomass till it became stabilized at about 0.016, and 0.022g/g/ day respectively when the phytomass attained its maximum (about 513.0, 466.0, and 1007.0g/m² respectively).

With respect to root productivity, there were slight fluctuations throughout all the periods, except the first and second period in which it followed the same trend as that in the shoot.

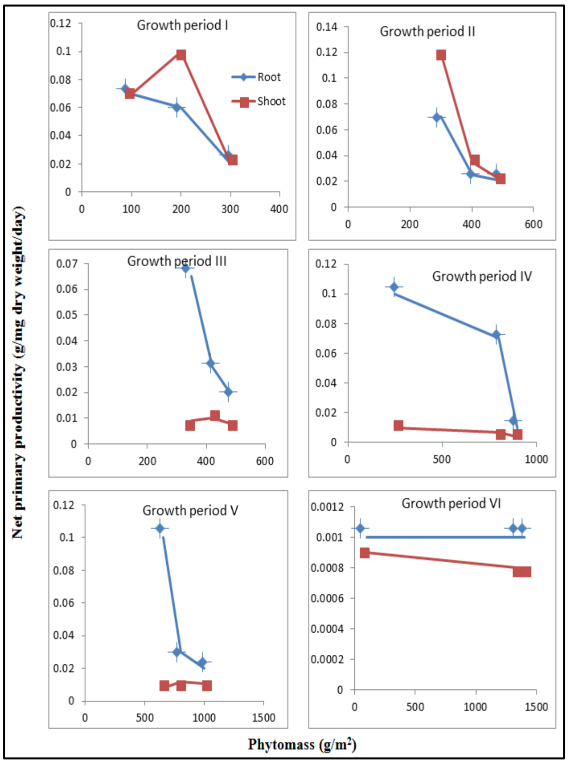

Fig. 3. Relationship between the net primary productivity and the phytomass in shoots and roots of *Trifolium alexandrinum* during six growth periods (I, II, III, IV, V and VI).

Nutrient allocation

The allocation of different nutrients relative to the biomass of shoots and roots of *T. alexandrinum* is indicated in Fig. 4. Most elements are concentrated in shoots during all the growth periods except the last one where all elements except N are diminished. The metabolically inactive roots show a more complex trend, thus except P, K and N all elements are diminished during the first second, and third growth periods. Mg accumulated during the last three growth periods, Na during the fifth and sixth, K during the fourth and fifth and Ca and P during the fourth and sixth growth periods. The content of different organic constituents (g/m^2) varied with plant organ and growth period (Table 3). Generally, the structural organic components (SOC) shared an average of about 75% of the total organic constituents in both the shoots and roots during all growth periods while crude protein (CP) and ether extract (EE) shared averages of about 16 and 8%, respectively in shoots, and about 13 and 9, respectively in roots. The TAC content was always higher in roots than in shoots; the sharing percentage was about 4 and 1% respectively. It is notable that the total content of organic constituents (g/m^2) increased with progress of the growth periods till a maximum was attained during the last growth period in shoots and roots.

Table 3. Variations in the mean content (g/m^2) of total organic constituents in shoots and roots of *Trifolium alexandrinum* at the end of different growth periods. Numbers in parentheses are percentages of the total.

Organ	Constituent				
	Total available carbohydrates (TAC)	Crude protein (CP)	Ether Extract (EE)	Structural organic components (SOC)	Total
Growth period I					
Shoot	4.99(2.09)	41.93(17.59)	22.35(9.37)	169.10(70.94)	238.37
Root	0.845(3.59)	3.731(15.87)	1.572(6.69)	17.350(73.83)	23.498
Growth period II					
Shoot	1.93(0.63)	45.56(14.92)	21.03(6.89)	236.73(77.55)	305.25
Root	2.600(2.26)	15.368(13.41)	7.716(6.73)	88.86(77.58)	114.54
Growth period III					
Shoot	2.80(1.10)	40.93(16.17)	19.75(7.80)	189.62(74.91)	253.10
Root	6.02(4.05)	20.443(13.77)	9.378(6.31)	112.59(75.85)	148.430
Growth period IV					
Shoot	8.12(1.45)	69.06(12.40)	43.23(7.76)	436.16(78.36)	556.57
Root	6.570(3.55)	15.910(8.61)	11.672(6.32)	150.52(81.01)	184.67
Growth period V					
Shoot	14.21(2.15)	89.55(13.58)	49.05(7.44)	506.31(76.80)	659.12
Root	8.836(3.63)	22.787(9.36)	14.586(5.99)	197.17(81.01)	243.38
Growth period VI					
Shoot	14.21(1.47)	129.10(13.40)	68.93(7.15)	750.94(77.96)	963.18
Root	8.058(3.25)	25.60(10.36)	22.208(8.97)	191.57(77.42)	247.43

Nutrient uptake

The total annual nutrient uptake (g/m² /year) was calculated by summing the amounts of nutrients removed by clipping and that retained by roots during the six growth periods (Table 4). The data presented in this table provide a guide to the amount of nutrients removed from the soil in the dry matter clipped in each growth period. The extent to which nutrients are removed varied considerably between growth periods. For example, the maximum removal of K (about 10.4g/m²) was during the fourth growth period; that of Na and Mg (about 11.4 and 7.1g/m² respectively) was during the fifth growth period, and that of N, P, and Ca (about 20.7, 0.813, and 7.9g/m², respectively) was during the sixth growth period. This occurred in spite of the dilution of all minerals during the last three growth periods (Fig. 4). The most prominent uptaken element during the season was N (about 73.7g/m²/ year) followed by Na and K (about 49.4 and 47.7g/m² year, respectively) Calcium came in the fourth order followed by Mg and P (about 35.2, 29.6, and 3.5g/m²/year, respectively).

Table 4. Total nutrient uptake (g/m²/year) in *Trifolium alexandrinum*.

Element / Growth period	N	P	K	Na	Ca	Mg
Growth period I						
Nutrient removed by clipping	6.71	0.276	5.64	6.20	3.10	0.931
Nutrient removed by roots	0.596	0.040	0.261	0.341	0.239	0.141
Total nutrient uptake	7.306	0.316	5.901	6.541	3.339	1.072
Growth period II						
Nutrient removed by clipping	7.29	0.372	5.58	4.09	4.09	2.45
Nutrient removed by roots	1.862	0.087	1.152	0.761	0.807	0.521
Total nutrient uptake	9.152	0.459	6.732	4.851	4.897	2.971
Growth period III						
Nutrient removed by clipping	6.55	0.292	5.41	3.80	4.15	2.42
Nutrient removed by roots	1.021	0.030	0.152	0.302	0.242	0.162
Total nutrient uptake	7.571	0.322	5.562	4.102	4.392	2.582
Growth period IV						
Nutrient removed by clipping	11.05	0.702	10.40	9.75	7.15	6.00
Nutrient removed by roots	0.928	0.058	0.626	0.514	0.509	0.991
Total nutrient uptake	11.978	0.760	11.026	10.264	7.659	6.991
Growth period V						
Nutrient removed by clipping	14.33	0.628	10.18	11.43	5.70	7.11
Nutrient removed by roots	1.219	0.079	0.539	2.149	0.186	1.021
Total nutrient uptake	15.549	0.707	10.719	13.579	5.886	8.131
Growth period VI						
Nutrient removed by clipping	20.65	0.813	7.75	9.93	7.90	5.54
Nutrient removed by roots	1.54	0.115	0.056	0.121	1.097	1.822
Total nutrient uptake	22.19	0.928	7.75	10.051	8.997	7.362
Total annual uptake	73.746	3.492	47.747	49.386	35.226	29.635

The average uptake (g/m²/growth period) is presented in Fig. 5. It is obvious that N is the element with the highest mean uptake compared to all other elements (12.3g/m²/ growth period).

Nevertheless the minimum level of N uptake in some growth periods was exceeded by that of K and Na (about 7.9 and 8.2g/m²/ growth period, respectively).

It may be noted that the mean P uptake in all growth periods was the lowest compared to other elements (about 0.58g/m² /growth period).

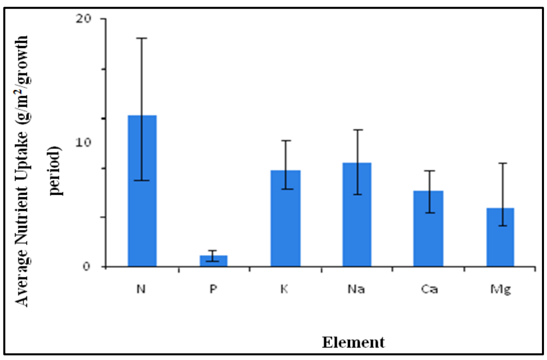

Fig. 5. Average uptake (g/m²/growth period) of different nutrients in *Trifolium alexandrinum*. Vertical bars represent the 95% confidence limits.

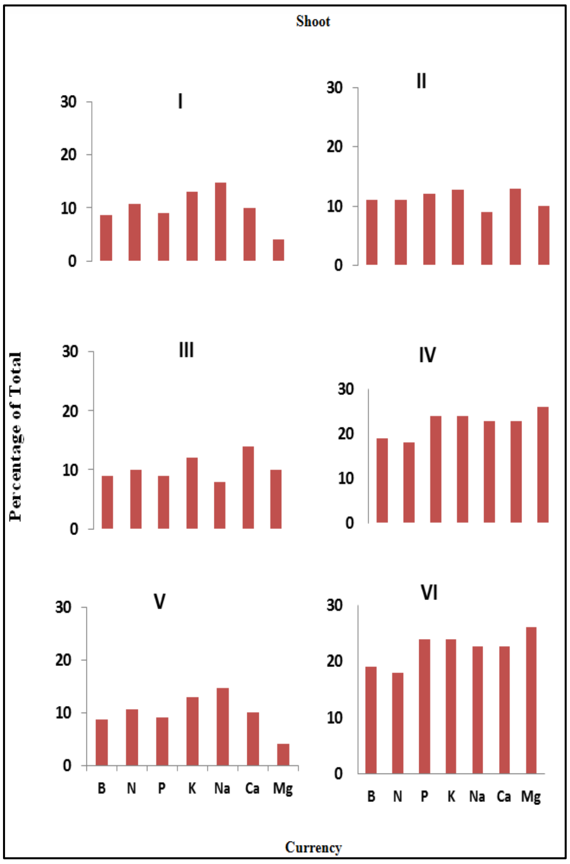

Fig. 4. Percentage of the maximum of biomass (B), and concentration of nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg) allocated to shoot and root of *Trifolium alexandrinum* six growth periods (I, II, III, IV, V and VI). Percentages of nutrients higher than that of biomass indicate increase in the concentration of nutrients, and lower percentages indicate their dilution.

Efficiency of nutrient-use or biomass per unit plant nutrient mass was also calculated from the data presented in Tables 2 and 4.

The maximum efficiency of K and Na-use (Fig. 6) was during the last growth period (about 1 and 132.0 respectively), while for Ca it was during the fifth growth period (about 171.2). P and N attained their maximum use-efficiency during the third and fourth growth period (about 1480.0 and 72.0 respectively).

The mean efficiency was always lower during the first growth period, except for Mg which attained its maximum use-efficiency during the first growth period (about 228.6).

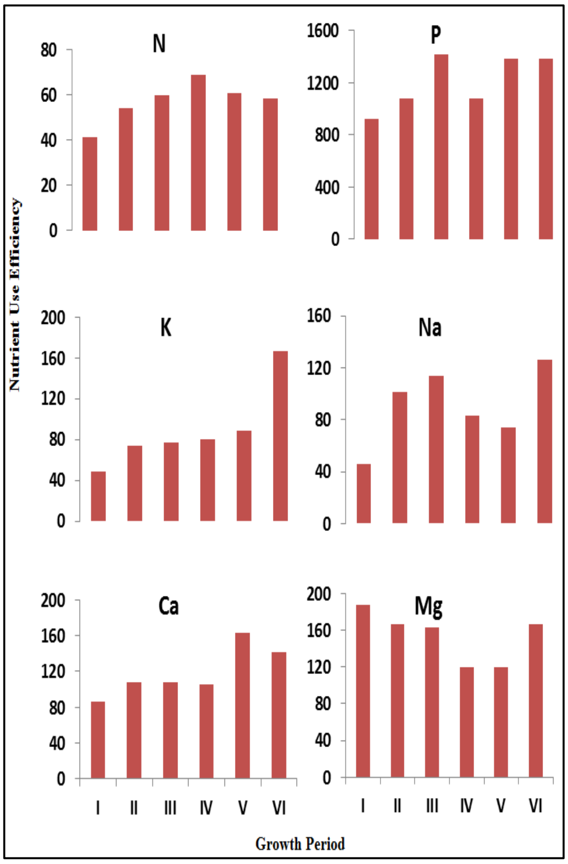

Fig. 6. Variations in nutrient use efficiency of *Trifolium alexandrinum* during different growth periods.

Discussion

Egypt suffers from the shortage of animal proteins and the competition between the major forage berseem clover and wheat on the limited available land in winter (Muhammad *et al.*, 2014). The demand for *Trifolium alexandrinum* has increased substantially in recent years as dairy farmers have become aware that they will achieve greater profits by increasing the proportion of good quality green feed used and consequently reducing the use of concentrates (Tufail *et al.*, 2016). During summer there is even a severe shortage of forage crops due to the competition between cereals and forage crops. As a result, animal production in Egypt is limited by low production of both winter and summer forages. Abdel-Sattar (1986) in a study on *Trifolium alexandrinum* cultivated in Alexandria University farm estimated the total dry forage yield in 1983 and 1984 as 11.1 and 16.9 tons/fed respectively, with an average of about 3 and 4.2 tons/fed respectively for each of the growth periods.

In desert ecosystem irrigated by Nile water where *T. alexandrinum* is under rotational grazing. Abdel-Razik (1990) estimated the maximum phytomass in three successive growth periods as about 1.6, 4.00 and 3.6 tons/fed respectively. In the first two growth periods, the shoot contributed about 76 of the total phytomass, while in the third growth period the shoots and reproductive organs contributed about 17 and 45% respectively of the total phytomass. The same author found that the maximum relative growth rate was about 0.09, 0.117 and 0.026g/g/ day respectively when the plant phytomass was about 50 435 and 535g/m^2 during the three growth periods. The higher green herbage yields of *T. resupinatum* obtained from the row distances of 20 and 30 cm were 13.92 and 17.95 ton/ha, respectively (Celena *et al.*, 2006).

In the present study, the total above-ground phytomass (forage) clipped continuously till the end of the growing season was about 14.3 tons/fed (leaves and stems, 13.23 tons/fed. and reproductive organs, 1.02 tons/fed). The rate of accumulation of dry forage was about 7.0g/m^2/ day during the first three growth periods while the maximum rate (about 27.0g/m^2/ day) was achieved during the last three growth periods. The above-ground net primary productivity (g/g dry weight/day) was estimated as about 0.066 and 0.93g/g/ day respectively during the first and the last three growth periods. For roots, the maximum net primary productivity (about 7g/g/ day) was attained in the first and second growth periods, while the minimum (about 0.004g/g/ day) was attained in the last four growth periods The above mentioned results indicate that the total annual dry forage production recorded in the present study (six growth periods) was in the range of that recorded by Abdel-Sattar (1986) in experimental farm (four growth periods), and exceeded that recorded by Abdel-Razik (1990) in the dry forage production in desert ecosystem. Moreover, growth period was higher in the experimental farm, followed by that in desert ecosystem than that estimated in the present study. The resource allocation patterns of biomass and or the various chemical elements are different.

Abrahamson and Caswell (1982) showed that in *Verbascum thapsus* (biennial weed), most nutrient with the exception of Na were concentrated in leaves, while stems exhibited dilution of all elements as in the roots again with the exception of Na, N, P, Mg and Cu were concentrated in the reproductive organs. They also concluded in a study on some *Solidago* species (perennial species) that nutrients were not allocated in the same manner as biomass. Gray (1983) estimated the percentage of annual accumulation of leaf N relative to biomass as about 78% in *Salvia* and 60% in *Artemisia* and *Ceanothus* when leaf biomass reached about 50% of the total. The same results were obtained by Rink *et al.* (2005) on Bermuda grass.

Data of the present study declared that the rate of nutrient accumulation in shoots was initially greater than the rate of biomass accumulation. For example, the percentages of N, P, K, Na, and Ca accumulated at 28% when the shoot biomass was about 30.9, 30.5, 37.0, 31.2 and 35.31 respectively. This trend occurred during the first three growth periods while in the last three growth periods the respective percentages were about 69.1, 69.5, 63.1, 68.8 and 64.74% when the shoot biomass reached about 72.1% of the total. This indicates a more rapid and greater sequestering of most elements in shoots during the early phase of the growing season. On the other hand, Mg exhibited a trend of accumulation during the last three growth periods most elements had a tendency for accumulation during roots the last three growth periods.

The forage crops must contain in addition to organic constituents, essential minerals such as P, S, Ca, Na, Mg, K and heavy metals. This is especially true in milk production, as dairy cows require considerable amounts of Na, Mg, Ca, and P (Mengel and Kirkby, 2001). For this reason pastures are often dressed with Na and Mg fertilizers, in order to increase the Mg and Na content of the herbage rather than to improve plant growth (Finger and Werk, 1973; Sun *et al.*, 2008). Sodic fertilizers can be used effectively to increase the concentration of Na in leaves of deficient pasture plants to levels suitable for grazing animals (Smith and Middleton, 1980; Wakeel *et al.*, 2011). The Mg availability in the young plant material (as in the first three growth period in the present study) is particularly poor (Pulss and Hagemeister, 1969).

The quantity of forage crops used as pasture or as hay depends on the digestibility of the fodder which decreases as the content of structural organic component (SOC) increases. Consequently, as these compounds are accumulated and the content of crude protein (CP) decreases, the quality of old forage crop is generally poor (Mengel and Kirkby, 2001) concluded that the content of CP 1979) in ryegrass declined and that of crude fibers (SOC) inclined over the growth period. Moreover, an increase in CP content is usually accompanied by a decrease in soluble carbohydrates (Nowakowski, 1962). Abdel-Sattar (1986) estimated the CP yield in *T. alexandrinum* as about 1133.4 and 931.0kg/ fed during the two growing seasons of 1983 and 1984 respectively. The present study reveals that the total organic constituents (TAC, CP, EE and SOC) in shoot attained their maximum content (about 4045 kg/fed) in the last growth period. Of the total, about 1.5, 13.4, 7.2, and 78.0% was contributed respectively by TAC, CP, EE, and SOC.

A quantitative descriptive model is constructed here in the form of a relational diagram that includes the available information on the clover agro-ecosystem and the relation between its different components (Fig. 7). This Fig. indicates the following: (1) there is a gradient of N and K concentration from a minimum in roots to a maximum in shoots, which is associated with active translocation of these elements to the shoot. The amount translocated exceeds 90% of the total up taken of N and K which is estimated at about 309.0 and 200.0kg/ fed/year. On the other hand, roots retain only less than 10% of these quantities. The concentration of P increases in the shoot in the first four growth periods; about 88% of the total phosphorus uptaken (14.6kg/ fed/year) is translocated to shoots in all growth periods. (2) The maximum translocation activity takes place during the second three growth periods, and contributes at least 67% of the total amount translocated during the growing season. (3) The amount of N, P and K retained by roots and afterwards returned to soil was about 9.7, 11.7 and 5.71 respectively of total amounts uptaken by clover plants. In the Mediterranean desert ecosystems of Egypt, Abdel-Razik (1990) reported that N, P, K and Ca attained the maximum translocation activity (about 50% of the total uptake) during the second growth period, and the amount of elements allocated to roots was about 64.2, 0.092, 48.2 and 28.9kg/ fed/year respectively. In a box-and-arrow diagram constructed for a stand of rangeland vegetation in the same region, Fakhry (1989) calculated the amount of N and total minerals (P + K + Ca + Na + Mg) translocated to the photosynthetic parts as about 72 and 26% of the total up taken elements which is estimated at about 122 and 2919mg/m²/m. In a well fertilized sugar beet field, Cooke (1982) and Niu *et al.* (2007) found that the amount of N uptaken (about 117.8kg/ fed/year) was equally divided between shoots and roots. A conservation mechanism was concluded for clover grown in desert ecosystems, where the amount of N allocated to roots was higher as compared with clover grown in Nile Delta (about 64.2 and 40.7kg/ fed/year respectively). The conservative mechanisms are common for plants grown in stressful conditions.

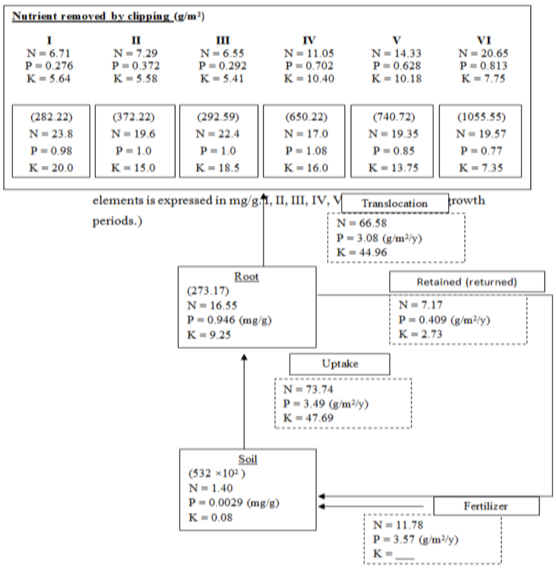

Fig. 7. A nutrient cycling model in the ecosystem of *Trifolium alexandrinum*. Fig.s between brackets represent the phytomass g/m², flows. Uptake and translocation are in g/m²/year, and concentration of elements is expressed in mg/g. I, II, III, IV, V, VI represent the growth periods.).

In field crops of agricultural importance the retained amounts of different elements in the phytomass are usually removed from the field. It is interesting to note that the amount of different elements removed by harvesting of *T. alexandrinum* was considerably higher than that removed from other crops, except for P which was exceeded by that in Bermuda grass.

A negative nutrient balance occurs unless nutrients are applied in the form of fertilizers or manures to substitute the amount removed by harvesting. Generally the more intensive the cropping system and the higher the yield, the greater must be the amount of nutrients applied in order to maintain soil fertility. The amount of N fertilizer a added represents about 16% of the total N uptake, where the remainder may be sustained by N fixed in nodules. Donald *et al.* (1983) estimated the amount of N fixed by *T. subterraneum* as about 90% of the total N up taken during the growing season.

The present study shows that the crop removes all the amount of P added in fertilizer, and slightly more than the amount of K present in soil pool. Thus one may conclude that the crop is nutritionally balanced and soil fertility is kept safe. Our results on nutrient use efficiency of (NTUE) indicate that *T. alexandrinum* behaves differently for nutrients use in the different growth periods. There are two possible mechanisms for such changes in whole-plant and ecosystem nutrient-use efficiency: (1) a change in nutrient concentration in most or all plants tissues and (2) a change in biomass allocation so that the relative abundance of tissues with different nutrient concentrations is changed. Pastor and Bockheim (1984) reported that an increase in root: shoot ratio with low nutrient availability might cause an increase in whole-plant efficiency in forests even if the nutrient concentration within roots or leaves did not change. Shaver and Melillo (1984) observed that the changes in efficiency of marsh plants were due to concentration changes alone. The results of the present study were consistent with those of Pastor and Bockheim 1984) and the main controlling factor in changes in foremost elements was due to biomass allocation and with Chaichi *et al.* (2015).

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