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Livestock production on Mediterranean grassland in relation to residual phosphate

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SUMMARY

Available pasture, liveweight gain, milk yield and supplementary feeding of Awassi sheep were monitored for four seasons (1991/92 to 1994/95) on pasture fertilized with superphosphate between 1984 and 1990. The experimental plots received three rates of phosphate (0, 25 and 60 kg P_2O_5/ha) annually, but no application after September 1990. The experiment was grazed at low (1·1 sheep/ha per year) and high (2·3 sheep/ha per year) stocking rates. The experimental site was typical of communally owned grasslands within the cereal zone of west Asia, where cropping is not possible because of shallow, stony soil and steep slopes. Plots with residual phosphate contained significantly more herbage and supported heavier animal liveweights, especially in the first two seasons. Milk yield and lamb production were greater and the need for supplementary feeding was reduced due to increased herbage. The results suggest that benefits of residual phosphate on pasture and livestock production can be considerable and should be included when assessing the value of applying fertilizer to degraded marginal lands in west Asia. Provided that the stocking rates remain within the range tested in the study, the pasture would suffer no harm. However, the higher stocking rates now practiced in the spring under communal grazing might severely limit flowering and seed-set. The property right to own or use the grazing land is seen as a key factor, deserving attention from governments in west Asia in order to apply new technologies to improve degraded marginal lands.

INTRODUCTION

An experiment was started in 1984/85 to test the hypothesis that the application of superphosphate to phosphate-deficient grassland (also called marginal lands, because grazing is the only possible use for them) which contain annual legumes stimulates the legumes, eliminates the nitrogen deficiency, and so leads to increased herbage production. Phosphate fertilizer was applied annually for 7 years, at 25 and 60 kg/ha P_2O_5. The treatment resulted in improved pasture productivity, especially the legume component (Osman *et al.* 1991), and in improved productivity of sheep grazing the pasture (Osman *et al.* 1994). Results also indicated that annual applications of phosphate raised the Olsen-P values in the soil from *c.* 7 mg/kg to *c.* 20 and 40 mg/kg for the two rates of P_2O_5 application at the end of the seventh season (July 1991). No more fertilizer was applied, and the experimental plots were used to study the effects of the residual phosphate on pasture and grazing animals.

Residual phosphate may contribute significantly to pasture and animal production in the following years, therefore such a contribution must be included in the final economic analysis of the study. Significant effects of residual P have been reported on succeeding crops in many countries of the Mediterranean basin (Kacar 1972; Orphanos 1988; Abdel Monem *et al.* 1990). In a previous study (Osman *et al.* 1999) the effects of residual phosphate on productivity and botanical composition of the pasture was recorded for six seasons. In the present paper, the effects of residual phosphate on animal production are reported during four seasons.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Tel Hadya Research Station (35° 55′N, 36° 55′E, altitude 362 m) of the International Center for Agricultural Research in the Dry Areas (ICARDA), 35 km south of Aleppo in north-west Syria. Tel Hadya has a mean annual

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Table 1. *Monthly October to April, rainfall and total annual rainfall (mm) at Tel Hadya from 1991/92 to 1994/95*

Season	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total
1991/92	73	25	74	62	75	16	—	326
1992/93	—	49	50	58	40	42	1	240
1993/94	13	46	19	113	140	15	13	358
1994/95	15	98	45	42	17	25	48	290

rainfall of 325 mm and a growing period of 6·5 months. The climate is typical Mediterranean: the rain falls from October to May, and summers are hot and dry. Monthly rainfall from October to the end of April for each of the four seasons of the experiment is shown in Table 1.

The experiment was conducted on undisturbed native grassland; the predominantly annual grass vegetation also included a few low shrubs, perennial grasses and herbs. The soils are calcareous, with pH between 7·8 and 8·4. The slope is moderate (3·7–7·2°), the ground is covered with stones (30–40%) and the soil is variable in depth (1–50 cm).

Treatments

Triple superphosphate, supplying 0 (referred to as P_0), 25 (P_{25}) and 60 (P_{60}) kg of P_2O_5 per hectare annually, and two stocking rates, low (1·1 sheep/ha per year) and high (2·3 sheep/ha per year), were included in the experiment when it was first established (1984/85). The experimental design was a randomized complete block with three replications, and the total area of the experiment was 85·5 ha. Triple superphosphate was applied from September 1984 until the end of 1990, but no fertilizer was applied thereafter. All fertilizer treatments in this paper, therefore, refer to the original fertilizer treatments.

One hundred and twenty-six Awassi ewes were allocated to groups, each with seven ewes aged 2–6 years old. Each group was permanently assigned to plots of 6·5 ha or 3·0 ha, representing the low and high stocking rates in each of the fertilizer treatments. The ewes grazed the plots for the whole year, from early morning to sunset, and were sheltered at night because of predators. Each year, the oldest ewe was replaced with a 2-year-old ewe, and sick and barren ewes were also replaced. The lambs were weaned at 60 days old. Other flock-management factors were as described by Osman *et al*. (1994).

Pasture productivity

Each year the pasture was sampled every 3–4 weeks, from early January until April. In the first two seasons (1991/92 and 1992/93), 30 samples per plot: 15 from inside protective cages (60 × 60 × 60 cm) and 15 from matched sites outside; the cages were relocated after each sampling. The number of samples per plot was reduced during the following seasons to 20 per plot (to minimize cost). Available herbage was estimated as the amount of herbage outside the cages, and the total herbage production was calculated by adding the increment in yield (difference in yield between inside the cages in the current sampling and outside the cages in the previous sampling) to the total yield of the previous sampling date.

Frequently the pasture was too short to cut using knives or cutter blades and it was necessary to take four cores (10·5-cm diameter) to a depth of 10 cm from within each quadrat. All samples were separated into legumes, grasses and other species. Roots were discarded and the shoot portion dried at 70 °C and weighed.

Sheep liveweights

Liveweight of ewes was recorded weekly for the 10 weeks before and 10 weeks after lambing. The sheep were shorn in May and wool production was recorded. At lambing in January and February, litter size, sex and birth-weight of lambs were recorded.

After lambing, the ewes were milked in the morning and evening and total daily milk production was recorded. When milk production fell below 200 g/day the ewes were milked once per day until it fell to 100 g/day, at which point it was gradually terminated. Lamb weights were recorded at birth and on a weekly basis through weaning.

Supplementary feeding

The sheep were fed straw and barley grain before mating, lambing and whenever liveweight fell below 43 kg. Cottonseed cake was added to the barley after lambing. The total feed consumed was expressed in megajoules (MJ)/animal, using conversion rates of 5·94, 11·90 and 8·72 MJ/kg energy values for barley straw, barley grain and cottonseed cake, respectively. The supplementary feed was formulated to supply the nutritional requirement for energy and protein for ewes over the year as affected by body weight, and production phase. These include pregnancy and lactation, milking, dry ewes and mating, as described by A. Goodchild and quoted by Nordblom *et al*. (1992), taking into account the feed availability in the pasture. Energy requirement was lowest in June at

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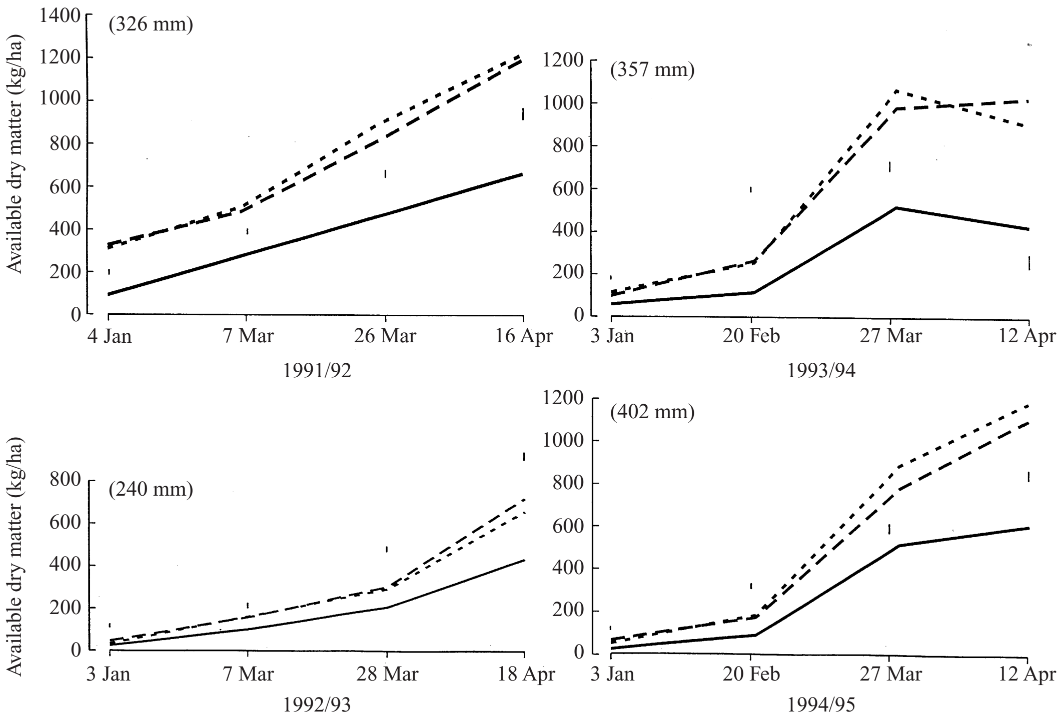

Fig. 1. Dry matter available to sheep (kg/ha) during four seasons under residual phosphate of 0 (——), 25 (- - -) and 60 (···) kg P_2O_5/ha (means of low and high stocking rates). Actual rainfall October to April in parentheses for each season. Vertical bars represent S.E.S (D.F. error = 10).

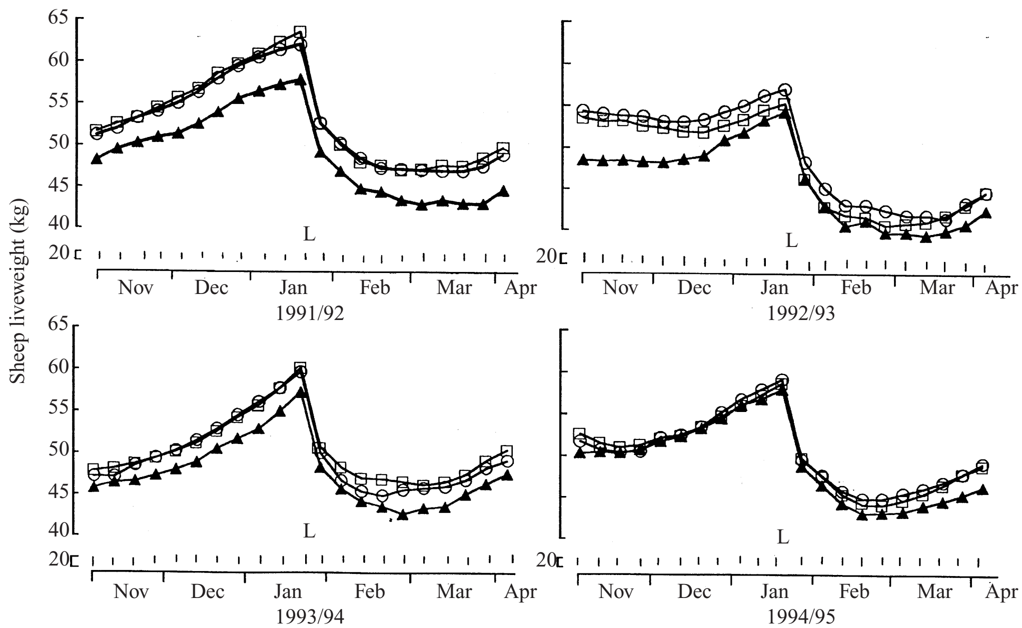

Fig. 2. Liveweight of ewes (kg) grazing grassland previously top-dressed with 0 (▲), 25 (○) and 60 (□) kg P_2O_5/ha before and after lambing (L). Data are from four seasons following the last application of phosphate fertilizer (means of low and high stocking rates). Vertical bars represent S.E.S (D.F. error = 10).

206 MJ/animal in the dry ewes and highest in February at 517 MJ/animal at peak lactation. Crude protein requirement per animal for the same 2 months was 1·68 and 4·66 kg/animal, respectively.

RESULTS

Available herbage

The pasture, which previously received phosphate application, contained significantly more herbage than the control in all seasons (Fig. 1). The differences were greater early in the season. For example, in an average rainfall season (1991/92, rainfall 326 mm), P_{25} contained 152% more total dry matter in January than P_0, while in April it contained 76% more. Similarly, in January of the dry season (1992/93, rainfall 240 mm) the same treatment yielded 91% over P_0, while in April the difference was 66%. The maximum herbage yield was recorded in the spring, ranging at P_{60} between 1223 kg/ha and 658 kg/ha. In a previous study of pasture productivity under residual phosphate (Osman *et al.* 1999) it was found that the legume proportion of the herbage was higher under P_{25} and P_{60} than under P_0.

Liveweights

Liveweights of ewes were heavier on plots previously dressed with superphosphate in all seasons (Fig. 2); however, the magnitude of difference varied (always $P < 0·05$ but sometimes $< 0·01$ or $< 0·001$). In 1991/92, the liveweights were significant ($P < 0·01$ or 0·001) for P_{25} and P_{60} over P_0 at all sampling dates, before and after lambing, while in 1992/93, there were more significant differences ($P < 0·01$ or $< 0·001$) before lambing than after lambing ($P < 0·05$). In 1993/94, the significant differences ($P < 0·05$) for P_{25} and P_{60} over P_0 started in week 5 before lambing through lambing and for P_{60} over P_0 ($P < 0·05$) in the second week after lambing throughout the rest of the sampling period. In 1994/95, the differences before lambing were not significant, but they were significant ($P < 0·05$) in favour of the phosphate-treated plots from week 6 after lambing onward. Ewe liveweights were consistently higher at low than at high stocking rates in all seasons. The differences were statistically significant ($P < 0·01$ or 0·001) in all sampling dates except for the 3 weeks after lambing in 1993/94 and in weeks 5 to 10 after lambing in 1994/95. In all years,

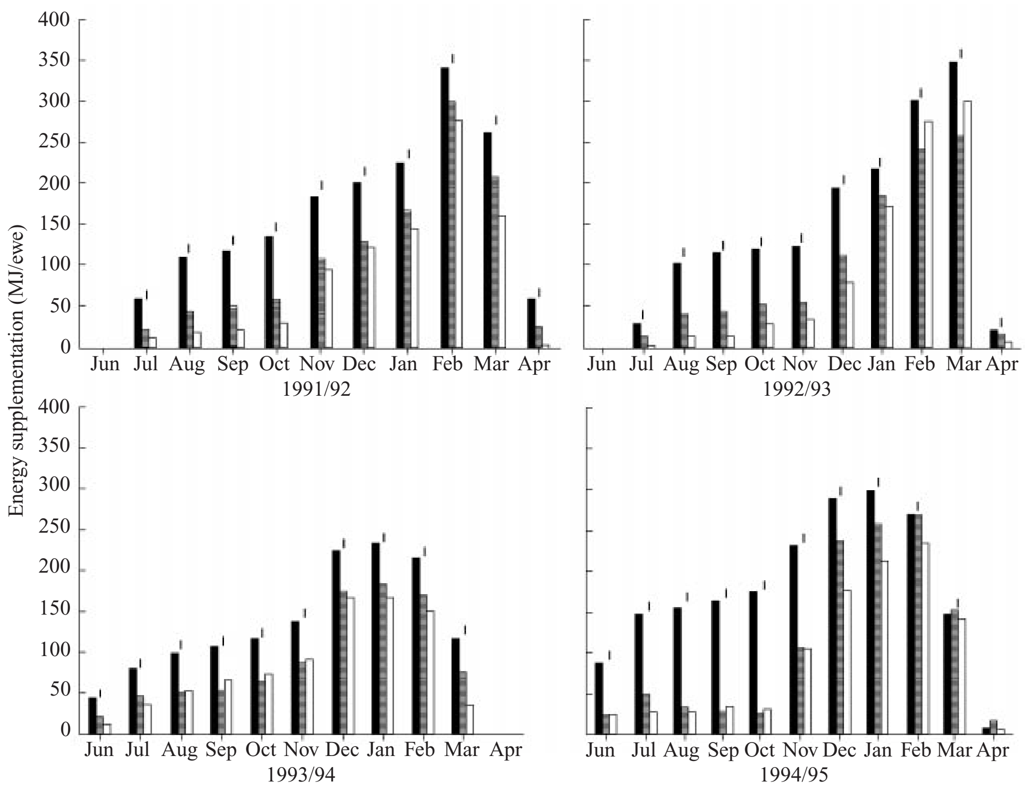

Fig. 3. Energy supplementation (MJ/ewe) for each month during four seasons following the last fertilizer application. The pasture was originally top-dressed with 0 (■), 25 (▥) and 60 (□) kg P_2O_5/ha (means of low and high stocking rates). Vertical bars represent S.E.S (D.F. error = 10).

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Table 2. *The cost (Syrian pounds/ha) of supplementary feed (barley grain, straw and cottonseed cake) for each of four seasons as affected by previous phosphate application* and stocking rate*

Phosphate treatment	Stocking rate	1991/92	1992/93	1993/94	1994/95
P_0	Low	717	905	465	947
P_0	High	4051	3317	3075	4052
P_{25}	Low	450	573	309	603
P_{25}	High	2706	2181	2011	2436
P_{60}	Low	302	497	79	339
P_{60}	High	2235	2016	2331	2372
S.E.		199·3	212·2	138·5	121·0
D.F. error			10	10	10

* Last phosphate application was September 1990.

Table 3. *Total milk production (kg/ha) during four seasons as affected by previous phosphate application* and stocking rate*

Phosphate treatment	Stocking rate	1991/92	1992/93	1993/94	1994/95
P_0	Low	43·2	66·5	65·0	79·1
P_0	High	99·7	104·8	117·5	137·5
P_{25}	Low	45·9	79·9	68·0	76·0
P_{25}	High	103·3	139·5	127·5	163·6
P_{60}	Low	57·7	88·3	66·9	87·0
P_{60}	High	121·2	155·5	137·9	149·5
S.E.		2·68	10·54	6·63	11·16
D.F. error		10	10	10	10

* Last phosphate application was September 1990.

weight differences were greater before than they were after lambing, and ranged between 3 and 7 kg in favour of the low stocking rates. Except in a few cases, the P × stocking rate was not significant in all sampling dates of all seasons.

Supplementary feeding

Maximum supplementary feed was recorded during the four seasons under P_0 (1430–2019 MJ/ewe) and high stocking rate (1540–1962 MJ/ewe). With few exceptions, the monthly energy supplementation was significantly higher ($P < 0{\cdot}01$ or 0·001) for P_0 over P_{25} and P_{60} in all seasons (Fig. 3). For example, in 1994/95 the energy consumption under P_0 exceeded the phosphate-treated plots in the range 15–525% during the period June–January, dropped to an equal amount of P_{25} in February, but exceeded P_{60} by 6–55% during February–April. More energy was fed at the high than at the low stocking rate in each year, the differences were significant ($P < 0{\cdot}01$ or $< 0{\cdot}001$) in all months except in February 1993 and February 1995.

There were few changes in the prices of the feed during the four seasons of this study. For example, the price of barley grain dropped from 8 Syrian pounds in 1992 to 7·85 in 1995, while the cottonseed cake increased from 8·56 to 9·75 Syrian pounds. The price of straw remained constant at 2·2 Syrian pounds. Maximum cost of feed was recorded for P_0 under high stocking rate in all seasons (Table 2). The overall increase in the cost of feed with time was generally due to the larger amounts consumed. For example, the energy consumption at P_0 in 1991/92 under low and high stocking rates was 952 and 2454 MJ/ewe, respectively, while in 1994/95 it was 1358 and 2681 MJ/ewe.

Milk production

Total milk production was greater under high than low stocking rate (Table 3). Similarly, the residual phosphate resulted in higher milk yield. For example, total milk yield for the four seasons under P_0 was 253·8 and 459·5 kg/ha under low and high stocking rates, respectively; for P_{25} it was 269·8 and 533·9 kg/ha, and for P_{60} it was 299·0 and 564·1 kg/ha.

In all four seasons the differences were statistically significant ($P < 0{\cdot}01$) for high over low stocking rate, while the difference was significant only in 1992/93 for P_{25} and P_{60} over P_0 control. Milk prices over the last four seasons, ranged between 19 and 20 Syrian pounds/kg.

Table 4. *Total lambs production (kg/ha) at weaning on native pasture during four seasons as affected by previous phosphate application**

Phosphate treatment	Stocking rate	1991/92	1992/93	1993/94	1994/95
P_0	Low	19·5	17·8	19·2	21·6
P_0	High	38·9	33·1	41·5	42·1
P_{25}	Low	21·0	19·9	20·1	21·4
P_{25}	High	38·9	35·4	41·5	45·3
P_{60}	Low	22·0	19·9	20·7	20·5
P_{60}	High	41·8	38·0	41·9	42·0
S.E.		0·52	0·56	0·55	0·56
D.F. error		10	10	10	10

* Last phosphate application was September 1990.

Lamb weights

Lambs gained weight at a faster rate on pastures, which had been previously dressed with phosphate, the differences being significant in the first two seasons. The average lamb at weaning (60 days from birth) was significantly heavier on the phosphate treated plots during 1991/92 and 1992/93. This was reflected in the total lamb production in kg/ha (Table 4). Similarly, the daily gain and final body weight of lambs were significantly greater at low over high stocking rate during the first two seasons. Market prices of lambs during the study period ranged between 90 and 95 Syrian pounds/kg liveweight.

DISCUSSION

Land degradation in west Asia is a phenomenon linked with increasing population and a rising demand for food. New technologies and management practices are called for in order to slow down or stop land degradation. A technology based on the conservation and utilization of native legumes and use of phosphate fertilizer was found effective in reversing degradation on non-arable lands in west Asia (Osman *et al*. 1991, 1997; Osman & Cocks 1992). Communally owned lands are non-arable lands, used mainly for grazing by sheep and goats. As such they are considered low-input systems, and users are not likely to invest in high-input technologies or when the technology is not likely to result in direct and valuable returns to them. The issue of land tenure is an important constraint to adoption of any technology and has to be resolved before any large-scale adoption of the technology can be expected. Applying phosphate was found to result in two direct benefits to the farmers: firstly, the saving associated with reducing the amount of supplementary feed and, secondly, increased production of meat and milk (Osman *et al*. 1994). Application of phosphate to crops under Mediterranean conditions is reported to have residual effects other than the effects during years of application (Kacar 1972; Orphanos 1988; Abdel Monem *et al*. 1990). Therefore, these effects must be included in the overall assessment of the fertilizer, especially on grazing lands, in order to encourage investment.

Our results confirmed that original phosphate fertilizer application continued to have considerable effect on pasture productivity, on body weight gain of the grazing animals, on milk production and on the saving associated with supplementary feed. In the first phase of the study (Osman *et al*. 1994), milk production was the only output used in calculating the benefits. In this study, both milk and lambs (meat) were included (Table 5). It must be noted that in most cases weaned lambs are kept for 2 or 3 months before

Table 5. *The benefits in Syrian pounds/ha* of the carry over effects of top dressing grassland with 25 kg P_2O_5/ha (P_{25}) or with 60 kg P_2O_5/ha (P_{60}) at low or high stocking rates, compared with no dressing control†*

Phosphate treatment	Stocking rate	1991/92	1992/93	1993/94	1994/95
P_{25}	Low	365	811	293	256
P_{60}	Low	940	1055	539	662
P_{25}	High	1417	1867	1266	2442
P_{60}	High	2530	2790	1183	1919

* One US Dollar = 42 Syrian pounds.

† The benefits were calculated from the savings obtained from reduced feed costs and from extra milk and lambs sales at weaning. The last phosphate application was September 1990.

selling, to take advantage of the high conversion rate of feed into meat by growing lambs (estimated at 4 kg concentrate per kg liveweight). Farmers who sell their weaned lambs would do so because of shortage of feed. For the purpose of the present analysis, we made the assumption that the farmer would sell the weaned lambs and use the pasture for the lactating animals.

At low stocking rate under P_{25}, the benefits ranged between 290 and 810 Syrian pounds/ha per season over the four seasons while under P_{60} the range was between 540 and 1060 Syrian pounds/ha. However, at high stocking these benefits become even more substantial, ranging between 1200 and 2400 Syrian pounds/ha for P_{25}, and 1100 and 2700 Syrian pounds/ha for P_{60}. Provided that the high stocking rates such as the ones tested here were kept constant in the spring, the pasture was found to suffer no harm (Osman *et al*. 1991). This is due to the fast growth of the pasture in the spring, resulting in high rates of flowering and seed-set. However, at higher stocking rates than the ones tested here (which are usually the case under communal grazing), the spring grazing severely limits flowering and seed-set (Osman & Cocks 1992). Therefore, ownership or the right to use the grazing land is a key issue, which deserves special attention from governments in order to apply new technologies to improve degraded marginal lands in west Asia.

The analysis in Table 5 did not include the value of wool, which showed no significant response to residual phosphate in any one season. It also ignores the effects that feed availability could have on animal health and fertility. Several studies have indicated that ewes are likely to conceive or bear twins when liveweight is high (Coop 1966; Fletcher 1971; Lindsay *et al*. 1975).

The results reported here suggest that phosphate fertilizer will continue to improve pasture productivity for several seasons beyond the years of actual application, and that the financial benefits could be substantial, especially when pasture is utilized at high stocking rates.

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