Iran Agricultural Research
Volume 1, No. 2, 1982

In the name of Allah

UREA AND AMMONIUM NITRATE AS SOURCES OF N FOR WHEAT, SUGARBEETS, AND CHICKPEAS[1] IN A 3-YEAR CROP ROTATION

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ABSTRACT

While urea is widely used by Iranian farmers, many of them are reluctant to use ammonium nitrate as the N source. The main objective of this experiment was to compare these fertilizers and to prove the acceptability of the latter source.

Wheat (*Triticum aestivum* L.), sugarbeets (*Beta vulgaris* L.) and chickpeas (*Cicer arietinum* L.) were grown successively (1972-75) under irrigation on a calcareous soil in southern Iran. Two sources of N (urea and ammonium nitrate) and triple superphosphate were tested at various rates.

Nitrogen fertilizers affected grain yield, percent protein, and protein yield of wheat. In most cases, the highest grain yield was obtained with 100 kg N/ha, but there was no statistical difference between yields from 50 and 100 kg N/ha, the means being 4650 and 4870 kg/ha of grain, respectively.

تحقیقات کشاورزی ایــــــران
جلد اول شماره دوم ۱۳۶۱

بنام خدا

استفاده از اوره و نیترات آمونیـــوم بعنوان کود ازته برای گندم، چغندرقند و نخود ایرانی در یک تناوب زراعی سه ساله.

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خلاصـــه

درحالیکه زارعین ایرانی از اوره بعنوان کود ازته بمیزان زیادی استفاده میکنند نسبت به مصرف نیترات آمونیوم جهت این منظور تمایلی نشان نمیدهند. هدف اصلی این آزمایش مقایسه این دو کود و اثبات قابل قبول بودن نیتـــرات آمونیوم بعنوان کود ازته بوده است.

گندم، چغندرقند و نخود ایرانی دریک تناوب سه ساله از ۱۹۷۲ تا ۱۹۷۵ درشرائط آبی درخاک آهکی درجنوب ایران کاشته شدند و دو منبع ازت (اوره و نیتـــرات آمونیوم) و سوپرفسفات تریپل با مقادیر مختلف مورد آزمایش قرار گرفتند.

کود ازته برروی محصول دانه، درصد پروتئین و عملکرد پروتئین گندم اثر داشت. دربیشتر حالات، بالاترین عملکرد دانه با اضافه کردن ۱۰۰ کیلوگرم ازت درهکتار بدست آمد اما تفاوت آماری معنی داری ازنظر محصول گندم بین ۵۰ کیلوگرم و ۱۰۰ کیلوگرم ازت درهکتار مشاهـــده نگردید و میانگین محصول بترتیـــب ۴۶۵۰ و ۴۸۷۰ کیلوگرم درهکتار بـــود. کاربرد ۲۰۰ کیلوگرم ازت درهکتار عملکرد را کاهش و میزان پروتئین را افزایـــش داد.

ازت و فسفر هردو موجب افزایش عملکرد چغندرقند شدند درحالیکه ازت بتنهائی مقدار قند را بالا برد. با افـــزودن ۱۰۰ کیلوگرم ازت و ۷۵ کیلوگرم فسفـــر در هکتار، میانگین عملکرد چغندرقنـــدو

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Application of 200 kg N/ha decreased grain production and increased its protein content.
Both N and P fertilizers increased sugarbeet yields, whereas N increased sucrose yield. With 100 kg N/ha and 75 kg P/ha, the mean yields of beet and sucrose were 31500 and 4780 kg/ha, respectively. Chickpea production was not significantly affected by the N and P treatments. The mean yield of grain was 2458 kg/ha.
In the three experiments with nine parameters measured, there were no significant differences due to source of N. Hence, the best choice between urea and ammonium nitrate would be the one costing the least.

میزان قندآن بترتیب ۳۱۵۰۰ و ۴۷۸۰ کیلوگرم درهکتار گردیدند. تیمارهای ازت وفسفر ازنظر آماری اثری برروی عملکرد نخود ایرانی نداشتند ومیانگین عملکرد ۲۴۵۸ کیلوگرم درهکتار بود. در هرسه آزمایش با اندازه‌گیری نه صفت مختلف هیچ اختلاف معنی داری بین دو نوع کود ازته دیده نشد. بنابراین انتخاب یکی از دو کود اوره یا نیترات آمونیوم بستگی به قیمت آنها خواهد داشت.

INTRODUCTION

Many workers have assumed that all N sources are equally effective, unit for unit of N applied, and their studies have involved the use of only one N source (4). However, according to Pesek (16), agronomic efficiency within and among sources of N varies with rate of application, time of application, placement, environment, crop, and physical and chemical properties of fertilizers.

Several N sources have been compared under conditions of established or newly-sown grasses. Nowakowski (13), using ammonium sulfate, calcium nitrate, ammonium nitrate, and urea found that the form of N fertilizer does not significantly affect the dry matter yield or N uptake of different grasses. Volk (21) tested the efficiency of urea, ammonium nitrate, and sodium nitrate on four types of grasses and did not find any consistent difference among these sources in yield or N concentration in forages. Loomis *et al.* (11) used five N sources on sugarbeets (*Beta vulgaris* L.) and found all sources to be equally effective in increasing the yield of beets.

Robertson and Hutton (17) evaluated six N sources on five general farm crops and found that no one source of N was consistently superior or inferior to the remaining sources tested, as far as the yield data of the cash crops in rotation were concerned. Chemical data on the soil samples indicated, however, that ammonium sulfate decreased pH, total N, Ca, and K concentrations. Response of irrigated corn (*Zea mays* L.) to time, rate, and source of N was studied by Jung *et al.* (9). They found that N source affected the yield and N concentration in the plant; however, responses to urea and ammonium nitrate were not significantly different.

Boratynki *et al* (2) found that urea was better assimilated than ammonium nitrate by young plants of mustards (*Brassica spp.*) and oats (*Avena sativa* L.), but the reverse occurred for mature plants. However, Devine and Holmes (5) observed that urea became less efficient compared to ammonium nitrate as the season advanced in grassland.

Several workers have indicated that plant responses to urea and ammonium nitrate may vary at different rates of application. In the experiments of Stephen and Waid (18) with 12 different plants, application of urea, ammonium nitrate, and ammonium sulfate at the lowest rates gave similar yields. At the intermediate and high rates, urea gave much lower yields than the other sources. In most crops, lower yields have been associated with urea-induced damage. Daigger and Moline (7) used three N sources for the production of hay meadows. In their experiment, there were no differences in hay yields among N sources at the low rates of 34 and 67 kg N/ha; however, at the highest N rate (135 kg N/ha), ammonium nitrate and sulfur-coated urea produced higher hay yields than urea. Templeman (19) summarizing the results of a series of grassland experiments, reached a similar conclusion and stated that "Urea appears to be less efficient more frequently at the heavier rates of application".

Results of many experiments have placed ammonium nitrate at a superior rating relative to urea. Burton and Devane (3) and Burton and Jackson (4) reported higher yields and

N recoveries by bermudagrass (*Cynodon dactylon* L. Pers. Hay) with ammonium nitrate as compared to urea. Devine and Holmes (6) summarized the results of 14 experiments conducted at various grasslands in England and concluded that urea gave lower yields than ammonium nitrate. They suggested that the conditions of low rainfall and the possibility of ammonia loss by volatilization may have contributed to a lower efficiency of urea. A similar conclusion was reached by Olson *et al.* (14) in corn, Lin and Wang (10) in rice (*Oryza sativa* L.), and Ostromecka (15) in oats. Ostromecka (15) conducted some experiments in water culture and suggested that ammonium nitrate due to its ionized state, penetrated into the root cells quicker than urea.

Vigue *et al.* (20) studied the nodulation of soybeans [*Glycine max* (L.) Merr.] grown hydroponically on different sources of N. They obtained better nodulation with urea as compared to ammonium nitrate and explained the difference to be due to a differential rate of uptake. Urea uptake by the plants was slower than NO_3 uptake, regardless of urea concentration supplied. Therefore, internal concentrations of N or N-components in the plant were likely lower with urea than with NO_3-nutrition which may have partially accounted for the degree and effectiveness of nodulation.

Addition of lime ($CaCO_3$) to the pure ammonium nitrate for decreasing its hygroscopicity and explosiveness is a common practice in many countries, including Iran. However, the suitability of this practice for the use on calcareous soils is questionable. While urea is widely accepted by the farmers, many of them are reluctant to use ammonium nitrate as a source for N. The present investigation was undertaken to compare the fertilizing value of these two N sources under a common crop rotation in the field and to prove the acceptability of the latter source. Furthermore, since P application is a common practice in all parts of Iran, attempt was made to test the comparisons under different P levels.

MATERIALS AND METHODS

Wheat, sugarbeets, and chickpeas were fertilized in a 3-year rotation program with four rates of N supplied from either urea (45% N) or ammonium nitrate (26% N) and three rates of P from triple superphosphate. The experimental design was a 2x3x4 factorial arranged as randomized complete block in four replications. Plot size was 4x10 m. The site was a Xerollic Calciorthid, fine, vermiculitic, thermic soil at the Kooshkak Experiment Station, 60 km North of Shiraz, Iran. The soil had a pH of 7.8 (saturated paste) and contained 2.2% organic matter, 0.1% N, 14 ppm sodium bicarbonate-soluble P, and 250 ppm ammonium acetate-soluble K. The annual fertilization rates and the total amount of fertilizers applied during the rotation experiment are presented in Table 1.

Wheat Experiment

In October 1972, plots were fertilized with four rates of N (0, 50, 100, 200 kg/ha) and three rates of P (0, 50, 100 kg/ha) and Roushan wheat (a local cultivar) was seeded at the rate of 120 kg/ha. The field was flood-irrigated prior to fertilization and seeding, and four subsequent irrigations were applied during the growing season supplemented with 24 cm of rainfall. In mid-June, 8 m^2 from the middle of each plot was harvested by hand, air-dried, threshed, and weighed for yield determinations. The proximate protein analysis was made on the ground subsamples by determining the Kjeldahl-N and multiplying by the factor 5.83 (23).

Sugarbeet Experiment

In April 1974, the same plots were prepared for this experiment. Sugarbeets were seeded at the rate of 20 kg/ha in

Table 1. Annual fertilization rates for rotation experiment from 1973 through 1975 (kg N + P/ha).

Treat-ment No.	Crop sequence			Total for 3 years
	Wheat (1973)	Sugarbeets (1974)	Chickpeas (1975)	
1	0 + 0	0 + 0	0 + 0	0 + 0
2	50 + 0	25 + 0	10 + 0	85 + 0
3	100 + 0	50 + 0	20 + 0	170 + 0
4	200 + 0	100 + 0	40 + 0	340 + 0
5	0 + 50	0 + 75	0 + 50	0 + 175
6	50 + 50	25 + 75	10 + 50	85 + 175
7	100 + 50	50 + 75	20 + 50	170 + 175
8	200 + 50	100 + 75	40 + 50	340 + 175
9	0 + 100	0 + 150	0 + 100	0 + 350
10	50 + 100	25 + 150	10 + 100	85 + 350
11	100 + 100	50 + 150	20 + 100	170 + 350
12	200 + 100	100 + 150	40 + 100	340 + 350

rows 60 cm apart. Rates of N were 0, 25, 50, and 100 kg/ha and rates of P were 0, 75, and 150 kg/ha. All rows were thinned after 3 weeks to make a uniform stand of 4 seedlings/m. The field was sprayed on May 26 and June 9 by Cottinexplus (active ingredients: D.D.T. 30%, lindane 9%, dimethoate 3.5%) at the rate of 2 kg/ha. During the growing season with no rainfall, plots were irrigated weekly and the beets were harvested in mid-October. Yield determinations were made on beets from 8 m of the four middle rows of each plot. Fresh beets were analyzed for sucrose concentration by a polarimeter

Chickpea Experiment

The same experimental plots were again used for this study. Chickpeas (Ommid cultivar) were seeded at the rate of 70 kg/ha in April 1975, in rows 50 cm apart. Rates of N were 0, 10, 20, and 40 kg/ha and those of P were 0, 50, and 100 kg/ha. There was no rainfall during the growing season and the plots were regularly irrigated at 8-day intervals. Plants from 8 m of the six middle rows were harvested, air-dried, and threshed for seed yield determinations. The proximate protein analysis was made on the ground seed samples by determining the Kjeldahl-N and multiplying by the factor 6.25 (23).

RESULTS AND DISCUSSION

Nitrogen rate was the only variable affecting the grain yield, percent protein, and protein yield of wheat (Table 2). In most cases, the highest grain yield was obtained with the application of 100 kg N/ha; however, there was no significant difference between 50 and 100 kg rates (Table 3). Comparing average grain yields of the plots receiving 50 kg/ha N from either urea or ammonium nitrate to that of check plots, indicates that urea produced only 20 kg grain per kg applied N as compared to 26 kg for ammonium nitrate. According to Devine and Holmes (5, 6), urea may leach from

Table 2. Coefficients of variation and significant treatment effects for 3 response variables of 3 crops grown in 3 years.

Crop	Response variable	C.V. (%)	P level (P)	N source (S)	N level (N)	PxS	PxN
			Sources of variation†				
Wheat	Grain	16.25	ns	ns	**	*	ns
	% protein	17.48	ns	ns	**	ns	ns
	Protein yield	24.23	ns	ns	**	ns	ns
Sugarbeets	Beet roots	12.37	**	ns	**	ns	ns
	% sucrose	9.76	ns	*	ns	ns	ns
	Sucrose yield	15.12	ns	ns	**	ns	ns
Chickpeas	Grain	18.32	ns	ns	ns	ns	ns
	% protein	5.01	ns	ns	ns	ns	*
	Protein yield	19.22	ns	ns	ns	ns	ns

†Interactions omitted from column headings were not significant.

*,**, ns Significant at the 0.05 and 0.01 levels, and not significant, respectively.

Table 3. Effects of N source and N-P rates on wheat grain yield, protein percentage, and protein yield in 1973.

N source	N P (kg/ha)	Grain (kg/ha) 0	Grain (kg/ha) 50	Grain (kg/ha) 100	Protein in grain (%) 0	Protein in grain (%) 50	Protein in grain (%) 100	Protein yield (kg/ha) 0	Protein yield (kg/ha) 50	Protein yield (kg/ha) 100
Urea	0	3359c*	3737bc	3483c	9.84d	9.59d	10.21cd	339d	363cd	365cd
	50	4230abc	4866ab	4471abc	9.08d	8.97d	9.21d	389bcd	438bcd	413bcd
	100	4771ab	5055a	4412abc	10.45cd	10.60d	10.45cd	502a-d	535abc	469bcd
	200	4379abc	4875ab	4327abc	13.34ab	13.74a	13.06abc	572ab	669a	552abc
Ammonium nitrate	0	3722cde	3186e	3490de	8.99c	9.07c	8.81c	333b	292b	310b
	50	4706abc	4156b-e	5476a	9.27c	9.46bc	10.18bc	442ab	392ab	554a
	100	4850abc	4845abc	5296ab	11.53abc	11.81abc	10.96abc	555a	571a	579a
	200	4155b-e	4064cde	4539a-d	13.44a	13.59a	12.80ab	570a	552a	580a

*From 12 means of each N source, those with the same letter are not significantly different at the 0.05 probability level (Duncan's test).

the soil without decomposition or after hydrolysis and subsequent nitrification. Winter temperatures might delay the formation of nitrate and reduce leaching, but if heavy rainfall occurs while considerable amounts of N remain as urea, extensive leaching may occur. Volatilization of ammonia may also contribute to the loss of urea remaining on the soil surface under low rainfall conditions. Differences between urea and ammonium nitrate in this experiment may have been due to a quicker penetration of ammonium nitrate into the root cells (15) and a lower N supplied from urea at the time of heavy plant demand. Application of 200 kg N/ha from either urea or ammonium nitrate sharply decreased the grain production. This is in agreement with our previous experiment (8) and the statement of Martin and Leonard (12) that "Heavy applications of N often reduce wheat yields not only by increasing plant lodging but also by delaying the maturity of the crop so that it is subject to greater damage from rust".

Grain yields were significantly increased by 50 kg N/ha, but the higher rates of N increased grain protein. This resulted in a significant increase in the protein yields at all N levels. The increase in protein yield was 1.21 kg per kg N from urea as compared to 1.72 kg from ammonium nitrate.

Phosphorus fertilizer increased the yield of sugarbeets significantly (Table 4), the mean increase being from 24485 kg/ha with "no P" to 27016 kg/ha for 150 kg P treatment. This means an increase of about 17 kg beet roots per kg applied P. Comparison of the effects of P under the two N sources indicates that each kg P increased beet roots about 12.5 kg under urea and 21.7 kg under ammonium nitrate. This shows a higher efficiency for P utilization under the latter source. Although the effect of P in the wheat experiment was not significant (Table 2), a similar trend in its comparative efficiency was observed (Table 3). The

Table 4. Effects of N source and N-P rates on sugarbeet yield, sucrose percentage, and sucrose yield in 1974.

		Yield of beet roots (kg/ha)			Sucrose in beet roots (%)			Yield of sucrose (kg/ha)		
N source	N P (kg/ha)	0	75	150	0	75	150	0	75	150
Urea	0	21745d*	22878d	24154a-d	14.57a	15.37a	14.62a	3189c	3507bc	3533bc
	25	25104bcd	23763cd	25045bcd	14.51a	14.85a	14.85a	3670bc	3515bc	3648bc
	50	24089cd	24961bcd	26497a-d	15.65a	15.75a	14.75a	3769bc	3870abc	3847abc
	100	28516abc	29922ab	30990a	15.27a	14.76a	15.25a	4332ab	4402ab	4728a
Ammonium nitrate	0	22787c	21615c	24180bc	15.46a	16.26a	17.15a	3502c	3524c	4149bc
	25	24505bc	26367bc	23412c	16.78a	15.79a	14.81a	4121bc	4147bc	3469c
	50	25391bc	26237bc	28972ab	15.60a	14.99a	14.55a	3962c	3943c	4363abc
	100	23745c	33073a	32878a	15.65a	15.61a	15.00a	3729c	5160ab	4956ab

*From 12 means of each N source, those with the same letter are not significantly different at the 0.05 probability level (Duncan's test).

reason may be a time-temperature interaction effect coupled with the reaction of ammonium with phosphates to make the latter more soluble, and also the possibility of the N loss from the surface-applied urea. Daily temperature maxima of above 15°C prevailed during the entire growing season, except for the first two weeks after planting. Apparently these temperatures favor the volatilization loss of N (22).

Effects of N source were not significant for beet roots or sucrose yield, and sucrose percent was only affected at the 0.05 probability level. Although with a coefficient of variability of 9.76% (Table 2), the significant inference for the effect of N source on the percent sucrose is justifiable, a close study of Table 4 indicates that the change in percent sucrose was not truly due to N source. In fact, the average sucrose percent of 15.00 for urea as compared to 15.67 for ammonium nitrate indicated an increasing effect for the latter source, while at each P level, ammonium nitrate produced a slight decreasing effect on the sucrose percent. The higher average for ammonium nitrate resulted from the high increase in sucrose percentage with P application under "no N".

Effects of N level on the yields of beets and sucrose were highly significant, but N application did not affect the sucrose concentration. The weight increase of beet root was from 22893 kg/ha for "no N" to 29854 kg/ha for 100 kg N treatment and the magnitude of this increase was higher for ammonium nitrate than for urea. Also, higher responses were usually obtained at lower levels of N from ammonium nitrate as compared to urea. According to Loomis *et al.* (11), inadequate N depresses yield, and adequate N for maximum yield depresses sucrose concentration. In this experiment, the higher trends in beet production under ammonium nitrate indicate a higher availability of this source of N as compared to urea. The effects of N levels on the sucrose concentration were not significant, showing that even the high levels were not sufficient to cause sucrose reduction under irrigation. However, N from ammonium nitrate had a slight, but not significant decreasing effect on the sucrose concentration. This also indicates a higher availability of this source of N, which may be beneficial under a different condition for other crops. Since N application in this experiment did not affect the sucrose concentration in beets, its effect on the sucrose yield was only a reflection of the beet root changes.

N source and N-P rates did not significantly affect chickpea yields and protein contents (Table 5), but the interaction between N and P was significant for percent protein. Legume crops, when effectively inoculated, are able to use atmospheric N through symbiotic N-fixation. Therefore, N does not seem to be a limiting factor for chickpeas. In general, use of N fertilizer on legume crops is not advocated or widely practiced. Martin and Leonard (12) have stated that N may not be needed on fertile irrigated soils when beans follow corn, potatoes (*Solanum tuberosum* L.) or sugarbeets that have been fertilized. The effect of P was also nonsignificant. Realizing the P status of the soil and the low responses of the previous crops in this rotation to P fertilization, this was not unexpected. According to Arnon (1) "In soils without marked nutrient deficiencies, chickpeas do not generally respond to mineral fertilization". He suggested an application of only 60-80 kg/ha P_2O_5 (26-35 kg P/ha) on P-deficient soils.

In conclusion, ammonium nitrate and urea proved to be equally efficient in all three experiments. Final decisions regarding the rate and source of N have to be based on the economics of inputs and responses.

Table 5. Effects of N source and N-P rates on chickpea yield, protein percentage, and protein yield in 1975.

N source	N P (kg/ha)	Grain (kg/ha) 0	Grain (kg/ha) 50	Grain (kg/ha) 100	Protein in grain (%) 0	Protein in grain (%) 50	Protein in grain (%) 100	Protein yield (kg/ha) 0	Protein yield (kg/ha) 50	Protein yield (kg/ha) 100
Urea	0	2317ab*	2487ab	2791ab	21.64a	20.50a	21.19a	504a	508a	591a
	10	2417ab	2294ab	2431ab	21.91a	21.50a	21.52a	530a	492a	525a
	20	2378ab	2858a	2584ab	21.17a	20.45a	20.78a	503a	585a	544a
	40	2462ab	2819ab	2068b	20.66a	22.19a	21.92a	505a	623a	456a
Ammonium nitrate	0	2152b	2646ab	2294ab	21.25ab	21.20ab	22.06a	459a	561a	508a
	10	2404ab	2398ab	2377ab	21.44ab	21.67ab	20.86ab	515a	521a	495a
	20	2351ab	2954a	2664ab	21.67ab	19.92a	21.95a	511a	585a	585a
	40	2337ab	2363ab	2163b	21.13ab	21.88a	20.80ab	492a	517a	495a

*From 12 means of each N source, those with the same letter are not significantly different at the 0.05 probability level (Duncan's test).

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