Asian Journal of Agricultural Extension, Economics & Sociology

17(4): 1-7, 2017; Article no.AJAEES.33863
ISSN: 2320-7027

Effect of Combine Application of Urea, Urease, Nitrification Inhibitors and Plant Growth Regulators on Spinach Productivity

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Authors' contributions

This work was carried out in collaboration between all authors. Author SN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JK and MZ managed the analyses of the study. Author SS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2017/33863
Editor(s):
(1) Zhao Chen, Department of Biological Sciences, College of Agriculture, Forestry and Life Sciences, Clemson University, USA.
Reviewers:
(1) Austin Phiri, Bvumbwe Agricultural Research Station, Malawi.
(2) Hamza Abdulmajeed, University of Ibadan, Ibadan, Nigeria.
(3) Mehmet Rustu Karaman, Afyon Kocatepe University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/19603

Original Research Article

Received 1st May 2017
Accepted 3rd June 2017
Published 19th June 2017

ABSTRACT

An experiment was conducted to assess the effect of applying different rates of urea treated with nBTPT (N-(n-butyl) thiophosphoric triamide) alone, or a combination of both nBTPT and DCD (Dicyandiamide) and DMPP (3, 4-Dimethylpyrazol-phosphate), on spinach productivity at experimental area of Faculty of Agriculture, Gomal University, Dera Ismail Khan during 2012-13. The experiment was arranged in a Complete Randomized Design (CRD) with nine treatments and four replications. Composite soil samples were collected before the experiment for various physico-chemical analysis viz soil texture, soil pH, organic matter, bulk density, NH_4-N, NO_3-N, extractable P and exchangeable K. The results showed that treatment (T6) with dose of Urea@150 kg/ha + GA3 @60 gram/ha was more effective than agrotain alone i.e tallest plant height (11.54 cm), maximum number of leaves (69), highest fresh weight (22.37g), highest dry weight (4.64 g), maximum

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biological yield (227 g pot^{-1}) and highest net return (13.42 million). Such findings may be due to availability of nitrogen for longer period and reduced loss on nitrogen by volatilization. The results further suggested that applying urea treated with Gibberellic acid (GA3) or Agrotain significantly increased the spinach growth. However, combine application of Urea, Urease, Nitrification Inhibitors and Plant Growth Regulators on Spinach productivity was better than urease inhibitor alone (agrotain).

Keywords: Agrotain; gibberellic acid; nBTPT; Spinach.

1. INTRODUCTION

Spinach (*Spinacia oleracea*) is an annual member of Chenopodiaceae family and a valuable vegetable which contains nutrients such as iron, calcium, phosphorus, sulfur, potassium etc [1]. Urea is the predominant form of N fertilizer worldwide and also in Pakistan (ca. 70%), principally because of its lower cost per unit of N, and the convenience for transport, storage and spreading, attributes which result from its higher N content (46% N), in comparison to the 35, 26, 21, and 18% N of ammonium nitrate (AN), calcium ammonium nitrate (CAN), ammonium sulphate (AS) and di-ammonium phosphate (DAP), respectively. However, urea has been reported to have lower N response efficiency (NRE), where NRE is defined as kg of additional dry matter (biomass and grain) produced per kg of applied N, when compared to other ammonium- and nitrate-based fertilizers. This is especially so if urea is applied under non-optimum soil moisture (very dry) and high temperature (above 20℃) conditions. The lower NRE of urea has always been attributed to the wide range of N losses (5% to 53% of the applied N) as ammonia (NH_3), when compared to AN, CAN, AS and DAP [2]. Of course, some N losses, like gaseous emissions of NH_3, nitric oxide (NO), nitrous oxide (N_2O) and molecular N (N_2) and immobilization by microorganisms to organic N, will be unavoidable because they are part of the natural N cycle and would occur after application of any ammonium-based fertilizer or dairy farm effluents. Hence, controlling the rate of all of these N losses is critical for improving the response efficiency of all chemical fertilizers.

During the past decade, researchers have developed a variety of management practices and technologies to improve the NRE of urea. One such approach is to treat granular urea with the urease inhibitor N-(n-butyl) thiophosphoric triamide (nBTPT - trade-name Agrotain®). The nBTPT is typically applied at a range of 250 to 500 mg per kg of urea in order to delay urea's hydrolysis by 7 to 10 days [3]. Several field and glasshouse studies have shown that treating urea with nBTPT (250 to 1,000 mg nBTPT per kg of urea-N) has the greatest potential to improve NRE in many cropping systems [4]. Similarly, urea can be treated with both nBTPT and nitrification inhibitors like dicyandiamide (DCD) or 3, 4-dimethylpyrazol-phosphate (DMPP) have gained commercial adoption in agricultural system. The soils of Pakistan are deficient in nitrogen [5].

Similarly, fertilizer use efficiency can be further improved if urea is applied with different additives like plant growth hormones or regulators [6]. The word 'hormone' came from Greek language, where it means 'to stimulate' or 'to set in motion'. Plant hormones/growth regulators (PGR) are a group of naturally occurring organic substances, which have the ability to influence physiological processes such as plant growth, differentiation and development, stress responses, cell division and reproductive activities when applied at a very low concentrations. Among the major classes of PGRs, auxins (generally represented by indole-3-acetic acid (IAA)), the gibberellins (GAs), and the cytokinins (CKs) have the most potential to be used as plant growth regulators. Curtailing processes with urease or nitrification inhibitors prolong the existence of nitrogen in soil giving greater opportunity to plants for its utilization and hence reducing chances of its volatilization [7]. The farmers are using nitrogenous fertilizers, mainly urea, to remove its deficiency as crops respond strongly to these fertilizers [8,9].

However, limited information is available on the effect of urea treated with nBTPT alone versus a combination of nBTPT and DCD or DMPP, and PGRs on plant productivity in hot climate conditions in Pakistan. Therefore, the objectives of this study are to investigate the effect of applying different rates of urea treated with nBTPT alone, or a combination of both nBTPT and DCD and DMPP, on productivity of spinach. Owing to the importance of spinach, and the effect of soil mineral nutrient content on its growth, yield and quality, this experiment was conducted to evaluate the effect of manure and urea on yield, nutrient uptake and nitrate accumulation in spinach.

2. MATERIALS AND METHODS

Pot experimental study was conducted at research farm of the Department of Soil and Environmental Sciences, Faculty of Agriculture, Gomal University, Dera Ismail Khan to assess the effect of applying different rates of urea treated with nBTPT alone, or a combination of both nBTPT and DCD and DMPP on spinach productivity. The experiment was laid out in Complete Randomized Design with following nine treatments containing four replications;

Treatments:	Description
T1:	No Nitrogen or GA_3 (Control)
T2:	Urea only @150 kg N/ha
T3:	Agrotain treated Urea @150 kg/ha
T4:	Agrotain treated Urea @150 kg/ha + DCD@10 kg/ha
T5:	Agrotain treated urea @150 kg/ha + DMPP@2 kg/ha
T6:	Urea@150 kg/ha + GA3 @60 gram/ha
T7:	Agrotain treated Urea @150 kg/ha + GA_3 @60 gram/ha
T8:	Agrotain treated urea@150 kg/ha + DCD @10 kg/ha + GA_3@60 gram/ha
T9:	Agrotain treated urea @150 kg/ha + DMPP@2 kg/ha + GA3@60 gram/ha

Experimental soil was crushed, passed through a 2 mm sieve and analyzed for different physical and chemical characteristics according to standard procedures. Such composite soil samples were collected before the experiment for various physico-chemical analysis viz soil texture, soil pH, organic matter, bulk density, NH4-N, NO3-N, extractable P and exchangeable K as shown in Table 1. In the diagnostic and research laboratory, the chemicals were used such as DCD (Powder) 10 kg per hectare, DMPP (Powder) 2 kg ha^{-1}, Agrotain Treated Urea 150 kg Nitrogen ha^{-1}, GA_3 60 gram ha^{-1} were used. In terms of agronomic analysis, plant height (cm), number of leaves per plant, fresh and dry weight (g) and biological yield (g pot^{-1}) was also measured. In case of economic analysis, economic yield index as net return (Rs. in million) was calculated for its extensive commercial cultivation. Data recorded for tested parameters were statistically analyzed for Analysis of Variance (ANOVA) to find out the significance of the studied parameters. Means of the studied parameters were compared by least significant difference ($LSD_{0.05}$) using Advanced Statistix 10 computer program [10].

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Results obtained on plant height of spinach as influenced by applying different rates of urea treated with nBTPT alone, or a combination of both nBTPT and DCD and DMPP, on spinach productivity are presented in Table 2. The findings showed that plant height varied significantly ($P<0.05$) among the treatments. The shortest plant height (5.88 cm) in spinach plants recorded from control treatment (T_1) where no fertilizer was applied, whereas tallest plant height (11.54 cm) was noticed from treatment (T_6) amended with Urea@150 kg/ha + GA_3 @60 gram/ha, followed by treatments (T_5 and T_8) respectively that differed significantly from all other treatments. The value of Least Significant Difference (LSD) as 2.5, indicated significant impact of Urea@150 kg/ha + GA_3 @60 gram/ha on the plant height of spinach in agro-climatic conditions of Dera Ismail Khan. This may be due to availability of N for longer period and reduced loss on N by volatilization. Previous study conducted by [11] pointed out that three types of organic manure alone produced moderate plant height and they were statistically similar with each other. Similar results findings were worked out by [12]. Previous studies conducted by [8,9] that farmers are using nitrogenous fertilizers, mainly urea, to remove its deficiency as crops respond strongly to these fertilizers.

3.2 Number of Leaves per Spinach

The results obtained on number of leaves per spinach as affected by applying different rates of urea treated with nBTPT alone, or a combination of both nBTPT and DCD and DMPP, on spinach productivity are presented in Table 2. The results revealed that number of leaves were varied significantly ($P<0.05$) among the treatments. The Minimum number of leaves (26) in spinach plants were recorded from control treatment (T_1) where no fertilizer was applied, while, maximum number of leaves (69) were recorded in spinach plants treated with Urea@150 kg/ha + GA_3 @60 gram/ha followed by treatments (T_7 and T_2) respectively that differed significantly from all other treatments. The value of Least Significant

Difference (LSD) as 15, showed highly significant impact of Urea@150 kg/ha + GA_3 @60 gram/ha on the number of leaves of spinach in agro-climatic conditions of Dera Ismail Khan. The similar findings of [13] revealed that interaction between concentration of GA3 and different soaking times plants treated with 10ppm for 24 hours gave maximum number of leaves per plant. Results findings of [14] revealed that maximum manure and urea application rates considerably enhanced yield of spinach; additionally the interaction of 300 kg urea/ha × 45 ton manure/ha resulted in enhanced yield by about 54% as compared to control.

3.3 Fresh Weight (g) of Spinach

The results obtained on fresh weight of spinach has showed that on average varied significantly ($P<0.05$) among the treatments in Table 2. The lowest fresh weight (8.52 g) in spinach plants recorded from control treatment (T_1) where no fertilizer was applied, while, highest fresh weight of 22.37 g was attained in spinach plants amended with Urea@150 kg/ha + GA_3 @60 gram/ha followed by treatments (T_7 and T_5) respectively that differed significantly from all other treatments. The value of Least Significant Difference (LSD) as 4.16, indicating highly significant impact of different combinations especially rates of Urea@150 kg/ha + GA_3 @60 gram/ha on the dry weight of spinach in agro-climatic conditions of Dera Ismail Khan. Past study conducted by [15] arrived at conclusion that any practice of maintaining a certain amount of NH4+-N in soil condition is greatly useful to producing an enhanced fresh weight of spinach and optimized biological yield with high quality of spinach. Similar studies by [16] concluded that the shoot fresh mass may be employed important index for the evaluation of NUE changes in spinach genotypes at the same N level due to high co-efficiency of variation recorded at low and high N levels in spinach production.

3.4 Dry Weight (g) of Spinach

The results obtained on dry weight of spinach revealed significant variation ($P<0.05$) existed among treatments as affected by applying different rates of urea treated with nBTPT alone, or a combination of both nBTPT and DCD and DMPP. The lowest dry weight (3.40 g) in spinach plants recorded from control treatment (T_1) where no fertilizer was applied, whereas, significant highest dry weight of 4.64 g was achieved on the application of Urea@150 kg/ha + GA_3 @60 gram/ha followed by treatments (T_9 and T_5) respectively that differed significantly from each other. The value of Least Significant Difference (LSD) as 0.7, indicated low level significant impact of Urea@150 kg/ha + GA_3 @60 gram/ha on the dry weight of spinach in agro-climatic conditions of Dera Ismail Khan. The findings of [15] revealed a combination of N nutrition at a ratio of 25:75 in hydroponics cultivation of spinach would optimize the fresh and dry biomass yield and quality of spinach.

Bottom line in the experimental trial of spinach conducted in study is that Urea@150 kg/ha + GA_3 @60 gram/ha considerably improved the dry weight in spinach plants over moderate rate of N or urea alone. GA_3 is proved instrumental in promoting seed germination, elongation of stem, growth of flowering and fruit in various commercial plants. These materials have crucial role in improving nitrogen management of spinach plants. Similarly findings were worked out by [17] arrived at conclusion that net nitrate uptake rate (NNUR) efficiency considerably enhanced with increasing trend of RGR. [3] also suggested reduced N losses via volatilization and enhanced pasture growth with combined application of urea and GA_3 as compared to urea alone.

3.5 Biological Yield (g pot^{-1}) of Spinach

The results obtained on Biological yield of spinach varied significantly ($P<0.05$) among the treatments. The lowest biological yield (202 g plot^{-1}) in spinach plants recorded from control treatment (T_1) where no fertilizer was applied, whereas, highest biological yield of 277 g plot^{-1} at treatment (T_6) was recorded in spinach plants amended with application of Urea@150 kg/ha + GA_3 @60 gram/ha followed by treatments (T_5 and T_3) respectively that differed significantly from all other treatments. The value of Least Significant Difference (LSD) worked out as 10.6, indicating overall significant impact of tested treatments especially highlighted dose of Urea@150 kg/ha + GA_3 @60 gram/ha on the biological yield of spinach grown in hot climatic environment of Dera Ismail Khan. Previous studies of [15] were in association with present study which revealed a combination of N nutrition at a ratio of 25:75 in hydroponic cultivation of spinach would optimize the biomass yield and quality of spinach. Any practice of maintaining a certain amount of NH4-N in soil condition is greatly effective in producing optimized yield with high quality of spinach. Moreover, the past research conducted by [14] pointed out highest application of manure and urea application rates resulted in increased spinach yield; furthermore, the interaction results (300 kg urea/ha × 45 ton manure/ha) also revealed enhanced yield by about 54% in comparison with control. The use of nitrogen inhibitors seems one of the promising strategies to reduce N losses from urea on calcareous alkaline soils provided other conditions are favorable such as soil organic matter and temperature [7]. [12] also showed that agrotain and dicyandiamide (DCD) in combination were more effective in minimizing NH3 losses and N2O emission, and in controlling urea hydrolysis, improving pasture production and retaining N in NH4+ form. Other researchers also observed similar results whereas the combined use of nitrification and urease inhibitors reported better results in terms of increasing crop yields than their use alone [18,19].

3.6 Economic Analysis of Spinach Yield

The computation of economic analysis of spinach production in Table 3 revealed that on average maximum Net Return (13.42 Million) was achieved by Treatment (T_6), followed by Treatments (T_5 and T_3) respectively. Hence that treatment (T_6) with dose of Urea@150 kg/ha + GA_3 @60 gram/ha in view of highest net return proved economical and financially feasible treatments for profitable production of spinach in hot climatic conditions of Dera Ismail Khan. These results are in accordance with the findings of [20] who revealed that growers are faced with the task of producing crops that achieve maximum yield, while limiting production costs, in order to maximize profit, minimize the environment impact, and produce a crop of extremely high quality that is demanded by today's consumers. Similar research work undertaken by [6] mentioned that the cost of treating urea with the AGROTAIN® would be in the range of US$ 66.00 to 68.00 per (metric) t of urea. The present studies were also on the analogy of [21] worked out that Benefit Cost Ratio (BCR) either on total cost container-1 bases (0.58: 1.00 and 0.76: 1.00) or on solution chemicals cost bases (1.25: 1.00 and 2.76: 1.00) were found significantly greater for Imai's recipe grown spinach crop.

Table 1. Physico-chemical characteristics of experimental soil

Characteristics	Unit	Value
Bulk Density	g cm^{-3}	1.39
pH	-	8.10
ECe	dSm^{-1}	1.13
Lime (CaCO3)	%	10.05
Organic Matter (OM)	%	0.92
Total Nitrogen	%	0.04
Available Phosphorus	µ g g^{-1} soil	7.10
Available Potassium	µ g g^{-1} soil	181.3
Clay	%	18.60
Silt	%	28.80
Sand	%	52.60
Textural Class	-	Sandy Clay Loam
Extractable Phosphorus	mg kg^{-1}	19.10
Exchangeable Potassium	mg kg^{-1}	189.20

Table 2. Plant height (cm), number of leaves, fresh weight (g), dry weight (g) and biological yield (g pot^{-1}) of Spinach

Treatments	Plant height (cm)	Number of leaves per Spinach	Fresh weight (g)	Dry weight (g)	Biological yield (g pot-1)
T1	5.88 d	25.5 d	8.52 d	3.40 c	202 d
T2	7.17 cd	62.75 ab	15.79 bc	4.30 ab	216 bc
T3	8.33 cd	53.50 bc	14.12 c	4.28 ab	223 ab
T4	7.79 cd	54.50 abc	14.32 c	3.90 bc	213 c
T5	10.99 ab	54.00 abc	17.63 bc	4.43 ab	225 abc
T6	11.54 a	68.75 a	22.37 a	4.64 a	227 a
T7	8.67 bc	65.50 ab	19.41 ab	4.29 ab	215 bc
T8	9.66 abc	36.25 c	16.59 bc	4.17 ab	216 bc
T9	9.53 abc	58.25 abc	16.57 bc	4.63 a	219 abc
LSD0.05	2.5	15	4.16	0.7	10.6

Means followed by similar letter(s) do not differ significantly at P0.05

Table 3. Economize nitrogen fertilizer in Spinach production

Treatments	Value of produce (Rs. in Million)	Cost of production (Rs. in Million)			Net return (Rs. in Million)
		Cost of produce	Cost of chemicals	Total	
T1	12.12	0.01	-	0.01	12.11
T2	12.96	0.01	0.01	0.02	12.94
T3	13.38	0.01	0.05	0.06	13.32
T4	12.78	0.01	0.26	0.27	12.51
T5	13.50	0.01	0.08	0.09	13.41
T6	13.62	0.01	0.19	0.20	13.42
T7	12.90	0.01	0.26	0.27	12.63
T8	12.96	0.01	0.47	0.48	12.48
T9	12.14	0.01	0.26	0.27	11.87

4. CONCLUSION

The study arrived at conclusion that almost all tested parameters were found instrumental especially dose of Urea@150 kg/ha + GA3 @60 gram/ha termed influential plant growth regulator for the sustained spinach productivity in hot climatic conditions of Dera Ismail Khan. There seems potential benefit of the combine application of Urea, Urease, Nitrification Inhibitors and Plant Growth Regulators on Spinach productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Peivast GA. Vegetables production. Agricultural Science Publi., Iran. (In Farsi); 2002.
2. Saggar M, King B, Zanesco A, MacLean K, Aichele S, Jacobs TL. Intensive training induces longitudinal changes in meditation state-related EEG oscillatory activity. Front. Hum. Neurosci. 2012;6:256.
3. Zaman M, Nguyen ML, Blennerhassett JD, Quin BF. Reducing NH3, N2O and NO3-N losses from a pasture soil with urease or nitrification inhibitors and elemental S-amended nitrogenous fertilizers. Biology and Fertility of Soils. 2008;44:693-705.
4. Soares AR, Pereira PM, Ferreira V, Reverendo M, Simes J, Bezerra AR, Moura GR, Santos MA. Ethanol exposure induces up-regulation of specific microRNAs in zebrafish embryos. Toxicol. Sci. 2012;127(1):18-28.
5. Shah Z, Shah MZ, Tariq, Bakht MJ, Rahman H. Survey of citrus orchards for micronutrients deficiency in Swat Valley of Khyber Pakhtunkhwa Pakistan. Pak. J. Bot. 2012;44(2):705-710.
6. Sturm H, Buchner A, Zerulla W. Gezielter dungen. Integriert-wirtschaftlich–umweltgerecht. (German) (Directed Fertilizer Use–Integrated–Economically–Environmentally sound). Verlags Union Agrar, DLG-Verlags- GmbH, Frankfurt am Main, Germany; 1994.
7. Ali R, Kanwal H, Iqbal Z, Yaqub M, Khan JA, Mahmood T. Evaluation of some nitrification inhibitors at different temperatures under laboratory conditions. Soil Environ. 2012;31(2):134-145.
8. Ehsanullah K, Jabran, Asghar G, Hussain M, Rafiq M. Effect of nitrogen fertilization and seedling density on fine rice yield in Faisalabad, Pakistan. Soil & Environ. 2012;31(2):152-156.
9. Ali A, Noorka IR. Nitrogen and phosphorus management strategy for better growth and yield of sunflower (*Helianthus annuus* L.). Soil Environ. 2013;32(1):44-48.
10. Steel RGD, Torrie JH, Dickey D. Principles and Procedures of Statistics: A Biometrical Approach, Third Edition, New York: McGraw-Hill, Inc; 1997.
11. Islam MM, Karim AJMS, Jahiruddin M, Majid NM, Miah MG, Ahmed MA, Hakim MA. Effect of organic manure and chemical fertilizers on crops in the radish-stem amaranth-Indian spinach cropping pattern in homestead area. Australian J. Crop. Sci. 2011;5(11):1370-1378.
12. Zaman M, Saggar S, Blennerhassett JD, Singh J. Effect of urease and nitrification inhibitors on N transformation, gaseous emissions of ammonia and nitrous oxide,

pasture yield and N uptake in grazed pasture system. Soil Biology and Biochem. 2009;41:1270-1280.
13. Akhtar N, Ibrar M, Aman N. The effect of different soaking times and concentrations of GA3 on seed germination and growth of *Spinacia oleracea* L. Pakistan J. Plant Sci. 2008;14(1):9-13.
14. Babakhanzade E, Sajirani M, Shakouri J, Mafakheri S. Response of Spinach (*Spinacia oleracea*) yield and nutrient uptake to urea and manure. Indian J. Sci. Tech. 2012;5(1):1953-1955.
15. Wang J, Zhour Y, Dong C, Shen Q, Putheti R. Effects of NH_4^+-N/$N0_3$-N ratios on growth, nitrite uptake and organic acid levels of spinach (*Spinacia oleracea* L). African J. Biotech. 2009;8(15):3597-3602.
16. Min-na L, Xiao-xia L, Wen-ya D, Qiu-hui C, Xian-yong L. Variation in nitrogen uptake and utilization efficiency in spinach genotypes and its evaluation. Journal of Zhejiang University. Agric. Life Sci. 2012; 38(5):599-607.
17. Margreet W, Steege T, Stulen I, Wiersema PK, Posthumus F, Vaalburg W. Efficiency of nitrate uptake in spinach: Impact of external nitrate concentration and relative growth rate on nitrate influx and efflux. Plant and Soil. 2006;208(1):125-134.
18. Dawar K, Khan I. Khan S, Khan MI. Impact of urease inhibitor (NBPT) and herbicide on wheat yield and quality. Pakistan J. Weed Sci. Res. 2010;17(2):187-194.
19. Nasima J, Khanif MY, Dharejo KA. Maize response to biodegradable polymer and urease Inhibitor coated urea. Intl. J. Agric. Biol. 2010;12:773-776.
20. Jeuffro MH, Ney B, Ourr A. Integrated physiological and agronomic modelling of N capture and use within the plant. J. Exper. Bot. 2002;53(370):809-23.
21. Shah AH, Muhammad S, Shah SH, Muneer S, Rehman M. Comparison of two nutrient solution recipes for growing spinach crop in a non- circulating hydroponic system. Sarhad J. Agric. 2009; 25(3):405-418.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19603