J. Soils and Crops 32 (1) 193-199, June 2022

ISSN 0971-2836 (Print)
ISSN 2582-2756 (Online)

IMPACT OF STRESS IRRIGATION MANAGEMENT THROUGH PARTIAL ROOT-ZONE DRYING ON YIELD AND SOIL PARAMETERS OF TOMATO (*Lycopersicon esculentum* Mill.)

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ABSTRACT

The field experiment was conducted at farm of AICRP on IWM, Mahatma Phule Krishi Vidyapeeth, Rahuri during summer season of 2018 and 2019 to evaluate the effect of Partial rootzone drying (PRD) on soil properties and uptake of tomato (*Lycopersicon esculentum* Mill.).The experiment was laid out in strip plot design with three replications. There were twelve treatment combinations. The three main plot treatments comprised of three drying cycles that is 7, 11 and 15 days. Whereas, sub plot treatments comprised of four irrigation levels *viz.,*60, 80, 100, and 120 % ET_C. The control treatment i.e. drip irrigation with 100% ET_C on every two alternate days was considered only for comparison and not included in statistical analysis. The results showed that the 7 days drying cycle showed maximum plant height and plant spread during both the years of investigation and at par with 11 days drying cycle during both years of study. Among the drip irrigation levels, the drip irrigation levels of 120% ET_C exhibited significantly higher plant height and plant spread during both years and also found at par with 100% ET_C drip irrigation level during both years. And among drying cycles, 7 days drying cycle obtained significantly maximal fruit yield (52.15,44.57 and 48.36t ha^{-1}) than remaining drying cycle and also at par with 11 days of drying cycle. The 120% ET_C drip irrigation level proved its supremacy by registering higher tomato fruit yield (55.79, 47.71 and 51.75 t ha^{-1} respectively) than remaining drip irrigation levels tried followed by 80 and 100 % ET_C drip irrigation levels. While in case of uptake of nutrients, drying cycle and drip irrigation level influenced significantly. Among the drying cycle,the 7 days of drying cycle registered significantly maximum uptake of nitrogen(118.69 and 101.52 kg ha^{-1}), phosphorus (32.72 and 26.92 kg ha^{-1}) and potassium (160.22 and 137.25 kg ha^{-1}) during both the years. While 11 days of drying cycle found at par with it during both the year under study. In case of drip irrigation level 120% ET_Cregistered significantly maximumuptake of nitrogen (128.33 and 110.00 kg ha^{-1}), phosphorus (34.88 and 28.83 kg ha^{-1}) and potassium (171.85 and 147.26 kg ha^{-1}) during first year and second year and 80 % and 100% ET_Cdrip irrigation level found at par with it during first year, second year and on pooled mean.Hence, Partial root zone drying is recent and effective irrigation method which improved uptake of nutrients and resulted increase in yield.

(Key words : Partial root zone drying, soil, yield, uptake, tomato)

INTRODUCTION

Tomato (*Lycopersicume sculentum* Mill.) is the important vegetable crop grow in India and also in the world. Tomato is very famous because of it's colour, juiciness and it's medicinal value. It is very good source of vitamins and minerals. The vitamin C in tomatoes is crucial for wound healing, strong teeth and bones, good immune system and promote iron absorption.

Tomato is grown worldwide in all climates and seasons to cater the demand of market and processing industry. Globally area under tomato is 5.03 million hectares, production of 180.77 MT and productivity of 35.93 tonnes ha^{-1} (Anonymous, 2019-20a). Total production of tomato in India is 190.07 lakh tonnes and productivity of 24.33 tonnes ha^{-1}(Anonymous, 2019-20b). Leading states of tomato production in India are Andhra Pradesh, Karnataka, Odisha, Telangana, West bengal, Gujarat, Chhattisgarh and Maharashtra. In Maharashtra total area under production is 45.50 thousand hectares and total production is 1086.56 thousand tonnes having productivity of 23.88 MT ha^{-1} (Anonymous, 2018).

Drought is a most common environmental stresses which limit agricultural production worldwide. Water availability has been reducing over years and it is expected that by 2030 (Bezbaruah and Borkotoki, 2020).Water is becoming an increasingly scarce resource for agriculture and good quality water is limited (Raut *et al.,* 2018). Restricted resources of fresh water and severity of droughts in arid and semi-arid regions are continuously ultimatum for food productions, so that it is tough to grow more crops or even

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to meet full biological plant demands (Badr *et al.,* 2018). Therefore, great prominence on the area of crop physiology and crop management under dry land situations with the aim to make plants more efficient in water use.

Among different irrigation methods, drip irrigation has proved it's superiority due to direct application of water into vicinity of crop root zone. However, research in water saving irrigation still are continued (Sleper *et al.,* 2007). Nowadays, full irrigation is taken as a luxury use of water which can be reduced with minor effect on crop yield (Kang and Zhang, 2004). Water-saving irrigations are used to improve the water productivity in recent period. Partial root-zone drying irrigation (PRD) is the water-saving irrigation method that reduced irrigation amounts of full irrigation to crops conventionally irrigated crops.

Partial root-zone drying irrigation (PRD) is the new irrigation strategy that is mainly adapted in the last decade to a vast kind of agronomic and horticultural crops to increase the water productivity (WP). Firstly, the idea of PRD was first applied by Grimes *et al.* (1968). Partial root drying (PRD) is a recent irrigation technique which enhances efficient use of water. Partial root zone drying is a new irrigation strategy based on split-root technology which involves alternatively wetting and drying of aroots.

PRD possibly apply in different ways depending on crops, method of irrigation, soil and environmental conditions. Partial root-zone drying is a successfully alternative irrigation compared to full irrigation that conserves water up to approximately 50%.

MATERIALS AND METHODS

The field experiment was conducted at farm of AICRP on IWM, Mahatma Phule Krishi Vidyapeeth, Rahuri-413722 during summer season of 2018 and 2019. Geographically, the Central Campus of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between $19^0$23' and $19^0$38' N latitude and between $74^0$39' and $74^0$65' E longitude.

The investigation was laid out in strip plot design with three replications. There were twelve treatment combinations including drying cycles as main plot treatment and drip irrigation levels as sub plot treatments. There were twelve treatment combinations. The three main plot treatments comprised of three drying cycles that is 7, 11 and 15 days. Whereas, sub plot treatments comprised of four irrigation levels *viz.,*60, 80, 100 and 120% ET_c. The control treatment i.e. drip irrigation with 100% ET_c on every two alternate days was considered only for comparison and not included in statistical analysis.

The plant height and plant spread were recorded in centimetres at harvest.The plant height was recorded from ground level to the tallest shoot part. For plant height five selected plants were used for observation.Number of fruits picked plant^{-1} was recorded from observational plants from each treatment. Yield ha^{-1} was also calculated.

Standard methods used for analysis of all soil parameters. The field capacity and permanent wilting point estimated by pressure plate apparatus (Richard 1947).Bulk density measured by clod coating method (Black and Hartage 1986). Soil pH determined by potentiometry method, and EC measured by Conductometry(Piper 1966).Organic carbon was determined following wet oxidation method (Nelson and Sommer, 1982). Available N was estimated by Alkalinepermanganate method (Subbiah and Asija, 1956); available P was estimated by Olsen method (Watanable and Olsen, 1965); and available K by Flame photometer as described by Knudsen *et al.* (1982). For Plant analysis, N measured by Micro-Kjeldhal's method (Anonymous,2005);P calculated by Vanadomolybdate yellow colour method (Jackson 1973); K by Flame photometer (Anonymous,2005).

The tomato observational plants were collected separately after last picking for chemical analysis. These plant samples were sundried for a period of 10 days and then kept in hot air oven at 65°C till constant weight was obtained. The dried plant samples were grinded in stainless still willey mill to fine powder and used for chemical analysis of N, P and K content tomato plant by using standard method. The uptake of NPK by tomato plant was worked out by multiplying the nutrient concentration to dry matter yield of tomato and expressed in kg ha^{-1} for each treatment.The data recorded were statistically analyzed by using technique of analysis of variance (Fisher, 1970) and significance was determined for strip plot design (Panse and Sukhatme, 1984). The standard error of mean (SE$\pm$) was worked out. Whenever, the results were significant, the critical difference (CD) at 5 per cent level of significance was worked out and presented.

RESULTS AND DISCUSSION

Growth and Yield

Among drying cycles, the drying cycles of 7 days to tomato showed significantly highest plant height and plant spread during 2018 and 2019 and found at par with 11 days of drying cycles during 2018 and 2019. The drip irrigation levels of 120% ET_Cexhibited significantly higher plant height and plant spread during both years of study and also found at par with 100% ET_Cdrip irrigation level. Partial root zone drying maintain proper moisture status in the area of root zone that increases the availability and uptake of nutrients which leads to increase in growth of crop. The 7 days drying cycle showed maximum number of fruits during both the years and at par with 11 days of drying cycle during both years. Application of **120%** ET_Cdrip irrigation level recorded higher number of fruits than remaining drip irrigation levels tried and at par with 80 and 100 % ET_C drip irrigation levels. The 7 days drying cycle obtained significantly maximal fruit yield (52.15, 44.57 and48.36t ha^{-1})than remaining drying cycle and also at par with 11 days of drying cycle during investigation years 2018 and 2019. Application of **120%** ET_Cdrip irrigation level proved its supremacy by registering higher tomato fruit yield (55.79, 47.71 and 51.75 t ha^{-1} respectively) than remaining drip irrigation levels tried and at par with 80 and 100 % ET_C drip irrigation level. According to Liu et al. (2006) PRD has positive effect on physiology and morphology of plants which play important roles in regulation of crop reproductive development, which directly affect quantitative and qualitative properties of yield. Partial root zone drying increased root development resulted in increase in uptake of nutrients which resulted in high yield.

Interaction effect

Interaction effects were found non-significant.

Soil physical and chemical properties

The field capacity, permanent wilting point and bulk density were calculated in physical property and in case of soil chemical properties viz., pH, EC, and organic carbon were calculated. Both the physical and chemical properties of soil not influenced significantly due to the different drying cycle and drip irrigation levels during years 2018 and 2019.

Interaction effect

Interaction effects were found non-significant.

Soil available nutrient

The available nitrogen, phosphorus and potassium of soil not statistically differed due to different drying cycle during both the experiment years. But the drip irrigation levels influenced significantly on available nitrogen, phosphorus and potassium in soil during years 2018 and 2019. The 60 % ET_C drip irrigation level recorded significantly maximum available nitrogen, phosphrous and potassium in soil followed by 80 % ET_Cdrip irrigation level during 2018 and 2019. The 120 % ET_C drip irrigation level noticed significantly minimum available nitrogen, phosphrous and potassium after harvest of crop during years 2018 and 2019.

Interaction effect

Interaction effects were found non-significant.

Nutrient uptake

The uptake of nitrogen, phosphorus and potassium was differed significantly due to different drying cycles and drip irrigation levels. The 7 days drying cycle registered significantly maximum uptake of nitrogen during first year, second year and on pooled mean and 11 days drying cycles found in second rank in respect of uptake of nitrogen, phosphorus and potassium by tomato plant. Significantly minimum uptake of nitrogen, phosphorus and potassium by tomato plant was observed under 15 days of drying cycle during both years.The 7 days drying cycle created congenial condition for enhancing the uptake of nutrients up to fruiting period. Dodd et al. (2015) also found that PRD improved crop nutrition, and re-wetting dry soil provokes biological changes which affected crop nutrient uptake.

In case of drip irrigation levels of 120% ET_C registered significantly maximum uptake of nitrogen, phosphorus and potassium during first year and second year. The 80 % and 100% ET_C drip irrigation level found at par with it in respect of uptake of nitrogen, phosphorus and potassium by tomato plant during first year and second year. Significantly minimum uptake of nitrogen, phosphorus and potassium by tomato plant was observed under 60% ET_C drip irrigation levels during both years.This is because of alternate drying and re-watering increase root growth which may enhance root biomass production which increases uptake of nutrient which result in high yield. Nahar and Gretzmacher (2002) revealed that the uptake of nitrogen, sodium, potassium, sulphur, calcium and magnesium was significantly reduced by water stress in the tomato plants.

Interaction effect

Interaction effects were found non-significant.

Results clearly showed that the drying cycle and drip irrigation level found significant in case of growth attributes,yield attributes and yieldduring both the years of study. The 7 days of drying cycle showed maximum plant height, plant spread, number of fruits and yield during both the years and at par with 11 days of drying cycle. The drip irrigation levels of 120% ET_c recorded maximum plant height, plant spread, number of fruits and yield during both years of study. The 80 and 100 % ET_c drip irrigation levels recorded at par number of fruits and yield during both years of study.In case of uptake of nitrogen, phosphorus and potassium by tomato plant, drying cycle and drip irrigation levels found significant during first year and second year.The partial rootzone drying irrigation had positively effect on root distribution and development of secondary roots which improved plants ability of nutrient uptake which resulted in increase in yield.

Table 1. Growth attributes, yield attributes and yield as influenced by drying cycle and drip irrigation level

Treatments	Plant height at harvest (cm)		Plant spread at harvest (cm)		No. of fruits plant^{-1}		Yield (t ha^{-1})	
	2018	2019	2018	2019	2018	2019	2018	2019
Main plot								
Drying cycles (D)								
D_1 - 7 days	101.60	99.24	67.63	57.20	28.67	25.04	52.15	44.57
D_2 - 11 days	98.76	95.70	66.30	55.18	27.78	24.16	49.81	42.55
D_3 - 15 days	90.32	88.13	57.98	50.68	27.07	23.44	45.46	37.36
SEm.±	0.98	2.06	1.83	0.90	0.28	0.28	1.18	1.16
CD at 5 %	3.80	8.05	7.15	3.52	1.10	1.08	4.60	4.52
Subplot								
Drip irrigation levels (I)								
I_1 – 60 % ET_C	81.51	80.54	57.02	46.44	24.91	21.82	39.51	32.23
I_2 – 80 % ET_C	100.06	96.61	62.83	54.10	27.47	24.11	48.73	41.45
I_3 – 100 % ET_C	102.28	99.78	66.74	57.74	28.82	24.99	52.54	44.59
I_4 – 120 % ET_C	103.73	100.49	69.28	59.13	30.16	25.94	55.79	47.71
SEm.±	0.81	1.00	1.11	1.11	0.78	0.56	2.44	1.98
CD at 5 %	2.79	3.42	3.82	3.82	2.70	1.92	8.40	6.82
Interaction (D X I)								
Between two sub plots means at same level of main plots means								
SEm.±	2.69	3.46	7.14	6.17	1.29	1.03	3.95	4.73
CD at 5 %	-	-	-	-	-	-	-	-
Between two main plots means at same level of sub plot means								
SEm.±	2.46	2.25	6.47	5.90	1.60	1.20	4.83	5.04
CD at 5 %	-	-	-	-	-	-	-	-
General mean	96.89	94.36	63.97	54.36	27.84	24.21	49.14	41.49
Control:Drip irrigation with 100 % ET_C	96.80	94.20	63.44	54.05	25.72	21.85	42.26	33.56

Table 2. Soil physical and chemical properties of tomato as influenced by different drying cycle and drip irrigation level

Treatments	Soil physical properties						Soil chemical properties					
	Field capacity (%)		Permanent wilting point		Bulk Density (g cm^{-3})		pH		EC (dSm^{-1})		OC (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Main plot												
Drying cycles (D)												
D_1 - 7 days	31.89	31.77	15.52	15.42	1.27	1.28	8.27	8.28	0.30	0.31	0.56	0.58
D_2 - 11 days	30.30	30.22	15.23	15.15	1.27	1.27	8.29	8.31	0.31	0.32	0.56	0.57
D_3 - 15 days	29.11	29.03	15.17	15.05	1.26	1.27	8.30	8.31	0.32	0.32	0.55	0.56
SEm.±	0.63	0.62	0.15	0.16	0.005	0.01	0.005	0.01	0.003	0.005	0.003	0.01
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
Subplot												
Drip irrigation levels (I)												
I_1 – 60 % ET_C	30.06	29.95	15.15	15.08	1.25	1.26	8.30	8.32	0.30	0.30	0.55	0.56
I_2 – 80 % ET_C	30.44	30.32	15.28	15.14	1.26	1.27	8.28	8.32	0.30	0.31	0.56	0.56
I_3 – 100 % ET_C	30.52	30.47	15.35	15.26	1.26	1.28	8.28	8.30	0.31	0.32	0.56	0.57
I_4 – 120 % ET_C	30.71	30.62	15.45	15.35	1.27	1.28	8.26	8.28	0.32	0.32	0.57	0.59
SEm.±	0.84	0.82	0.23	0.22	0.01	0.01	0.01	0.01	0.005	0.01	0.003	0.01
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
Interaction (D X I)												
Between two sub plots means at same level of main plots means												
SEm.±	1.24	1.23	0.32	0.32	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
Between two main plots means at same level of sub plot means												
SEm.±	1.45	1.42	0.39	0.38	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
General mean	30.43	30.34	15.31	15.21	1.26	1.27	8.28	8.30	0.31	0.31	0.56	0.57
Control:Drip irrigation with 100 % ET_C	30.35	30.28	15.25	15.10	1.25	1.26	8.29	8.32	0.31	0.32	0.55	0.56
Initial	30.46	30.30	15.32	15.28	1.27	1.27	8.32	8.30	0.30	0.30	0.53	0.53

Table 3. Soil available and uptake of nutrient of tomato as influenced by different drying cycle and drip irrigation level

Treatments	Soil available nutrients (kg ha^{-1})						Nutrient uptake (kg ha^{-1})					
	Nitogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Main plot												
Drying cycles (D)												
D_1 - 7 days	231.77	229.61	16.51	16.42	440.39	435.30	118.69	101.52	32.72	26.92	160.22	137.25
D_2 - 11 days	234.52	230.56	17.26	17.20	442.32	437.13	112.75	96.41	30.22	25.20	152.02	130.38
D_3 - 15 days	238.58	234.78	18.56	18.34	446.10	440.75	101.44	83.68	26.67	20.97	137.49	113.16
SEm.±	1.51	1.86	0.48	0.54	2.19	1.74	2.93	2.98	0.91	0.80	3.86	3.73
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
Subplot												
Drip irrigation levels (I)												
I_1 – 60 % ET_C	238.09	234.36	18.33	18.12	447.80	441.68	87.20	71.45	23.09	18.04	118.75	97.01
I_2 – 80 % ET_C	235.24	232.73	17.26	17.14	443.56	438.44	108.97	92.45	29.37	24.07	148.20	126.31
I_3 – 100 % ET_C	233.72	230.93	17.13	17.07	441.72	436.50	119.34	101.58	32.13	26.51	160.83	137.14
I_4 – 120 % ET_C	232.78	228.58	17.06	16.94	438.67	434.28	128.33	110.00	34.88	28.83	171.85	147.26
SEm.±	1.04	1.22	0.24	0.22	1.68	1.43	5.70	5.92	1.62	1.47	7.01	6.22
CD at 5 %	3.50	4.20	0.80	0.78	5.75	4.94	19.6	17.89	5.62	5.04	24.26	21.52
Interaction (D X I)												
Between two sub plots means at same level of main plots means												
SEm.±	2.76	3.36	1.06	0.73	3.75	3.58	11.25	9.36	3.52	2.75	12.50	11.08
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
Between two main plots means at same level of sub plot means												
SEm.±	2.20	2.54	0.84	1.17	3.09	3.18	12.73	10.19	3.85	3.15	14.52	12.72
CD at 5 %	-	-	-	-	-	-	-	-	-	-	-	-
General mean	234.96	231.65	17.44	17.32	442.94	437.73	111.96	93.87	29.87	24.36	149.91	126.93
Control:Drip irrigation with												
100 % ET_C	235.40	232.92	17.34	17.26	443.92	438.90	95.08	75.29	25.45	19.00	128.48	102.26
Initial	236.42	233.25	18.24	17.42	446.75	440.45	118.69	101.52	32.72	26.92	160.22	137.25

REFERENCES

Anonymous, 2005. Official Methods of Analysis. 16th Edn. Association ofOfficial Analytical Chemists ,Washington D.C.

Anonymous, 2019-20b.Area and production of horticulture crops for 2020-21. National Horticulture Board, Ministry of Agriculture and Farmers' Welfare, Government of India, Gurgaon, Haryana.

Anonymous, 2019-20a. Food and Agriculture Organization Corporate Statistical Database. (FAOSTAT)

Anonymous, 2018. Horticultural statistics at a glance, published by Horticulture Statistics Division, Ministry of Agriculture & Farmers' Welfare, Government of India, New Dehli.

Badr, M. A., W.A. El-Tohamy, S. D. Abouhussein and N. Gruda, 2018. Tomato yield, physiological response, water and nitrogen use efficiency under deficit and partial root zone drying irrigation in an arid region. J. Appl. Bot.Food Qual.**91**: 332-340.

Bezbaruah Ranjita and Borkotoki Bikram, 2020.Impact of water management on growth and yield of early AHU Rice variety through on-farm trial in Morigaon District of Assam J. Soils and Crops. **30**(2):260-263.

Black, C.A. and K.H. Hartage, 1986.Particle density and bulk density.In method of soil analysis Part-I. Physical and Mineralogical methods. Soil Sci. Soc. Am. **9:**363-383.

Dodd, I. C., J. Puertolas, K. Huber, J. G. Perez-Perez, H. R. Wright and M. S. Blackwell, 2015. The importance of soil drying and re-wetting in crop phytohormonaland nutritional responses to deficit irrigation. J. Expe. Bot.**66** (8): 2239–2252.

Fisher, R.A. 1950. Statistical methods for research workers. 11th edition. Oliver and Boyd, London. pp. 85.

Grimes, D.W., V.T. Walhood and W.L. Dickens, 1968.Alternate-furrow irrigation for San Joaquin valley cotton. California Agri.**22**: 4-6.

Jackson M. L. 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd, New Delhi, pp.498.

Kang, S. and J. Zhang, 2004. Controlled alternate partial root-zone irrigation: its physiological consequences and impact on water use efficiency.J. Expe. Bot.**55**(407): 2437–2446.

Knudsen, D., G. A. Paterson, and P. F. Pratt, 1982.Lithium, Sodium, Potassium.In methods of soil analysis, Part-II chemical and microbial properties**.** Agro.Monographs. **No. 9 :**225-238.

Liu, F., A. Shahnazari, M.N. Andersen, S.E. Jacobsen and C.R. Jensen, 2006. Physiological responses of potato (*Solanum tubersum* L.) to partial root-zone drying: ABA signaling, leaf gas exchange and water use efficiency. J. Expe. Bot. **57** : 3727-3735.

Nahar, K. and R. Gretzmacher, 2002. Effect of water stress on nutrient uptake, yield and quality of tomato (*Lycopersicon esculentum* Mill.) under subtropical conditions. Die Bodenkultur.**53** (1):45-51.

Nelson, D.W. and L.E. Sommer, 1982.Total carbon and organic matter.In method of soil analysis. Part-II AC.(Ed). Am SocAgron.Inc. Soil Set Am. Inc. Madison, Wisconsin, USA. pp. 539-579.

Panse, M.A. and P.V.Sukhatme, 1967.Statistical methods for agricultural workers.IInd End. ICAR, New Delhi. pp. 135-136.

Piper, C.S. 1966. Soil and plant analysis.Hans Publishers, Mumbai.pp. 19-136.

Raut, Maya, Shalini Badge, Damayanti Guldekar, Vandana Madke, Kavita More, 2018. Impact of effluents irrigation on soil and crop productivity of Gumthala village of Nagpur district. J. Soils and Crops.**28**(2):374-381.

Richard, L.A. 1947.Pressure membrane apparatus, construction and use.Agriculture Engineering.**28**:45-54.

Sleper, D.A., S.L. Fales and M.E. Collins, 2007. Foreword. In: Irrigation of agricultural crops (R.J. Lascano and R.E. Sojka, eds.), 2nd edition, Agronomy Monograph no. 30.

Subbiah, B.V. and G.L. Asija, 1956. A rapid procedure for the estimation of available nitrogen in soil.Curr. Sci. **25**:259-260.

Watnabe, F.S. and S.R.Olsen, 1965. Test of an ascorbic acid method for determining in water and sodium carbonate extract from soils. Soil Sci. Soc. Am. J. **29**:677-678.

Rec. on 10.12.2021 & Acc. on 21.12.2021