ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
Special Issue: 14 (SI), 192 - 198 (July, 2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Microirrigation and establishment methods for water use studies, fodder yields and postharvest available nutrients on Bajranapier hybrid grass [CO (BN) 5]

S. V. Varshini*
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India
C. Jayanthi
Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India

*Corresponding author. Email:varshuagri08@gmail.com

Article Info
https://doi.org/10.31018/jans.v14iSI.3608
Received: March 10, 2022
Revised: May 9, 2022
Accepted: June 12, 2022

How to Cite
Varshini, S. V. and Jayanthi, C. (2022). Microirrigation and establishment methods for water use studies, fodder yields and postharvest available nutrients on Bajranapier hybrid grass [CO (BN) 5]. *Journal of Applied and Natural Science*, 14 (SI), 192 - 198. https://doi.org/10.31018/jans.v14iSI.3608

Abstract
The availability of quality fodder is becoming a major concern in India. To address this, a field experiment was conducted on bajranapier hybrid grass CO (BN) 5 (Interspecific hybrid between Cumbu (*Pennisetum glaucum*) and Napier (*P. Purpureum Schumach*) during 2018-19 in strip plot design with 3 replications. Treatment comprises of main plot *viz.,* Irrigation methods sub plot *viz.,* Crop establishment methods. The results showed that in water use studies, higher WUE (23.74 t/ha/mm) was recorded with sbsurface drip irrigation. Similarly, higher water productivity (WP) (0.024 t/m$^{3)}$ and economic WP (474.78 ₹/ha/mm) were also with the same. In crop establishment methods, horizontal planting of setts with settling treatment recorded higher WUE (21.47 t/ha/mm), WP (0.021 t/m^3) and economic WP (429.43 ₹/ha/mm). Significantly higher (0.05 %) green (335.0 t/ha/year) and dry fodder yields (71 t/ha/year) were registered with subsurface drip irrigation (M_3). In crop establishment, horizontal planting of setts with settling treatment (S_2) registered higher green (331.5 t/ha/year) and dry (71.4 t/ha/year) fodder yields.On postharvest soil available nutrients, higher N (172.3 kg/ha), P (22.2 kg/ha) and K (591.5 kg/ha) were observed with surface irrigation. Vertical planting of setts without settling treatment recorded higher N (172.1 kg/ha), P (23.3 kg/ha) and K (604.8 kg/ha). By adopting this subsurface drip irrigation with horizontal planting of setts with sett treatment, the bajranapier hybrid grass cultivation can be optimized for the betterment of cultivation.

Keywords*:* Crop establishment, Fodder yields, Irrigation methods, Postharvest available nutrients, Water use efficiency

INTRODUCTION

Studies have estimated that India accounts for nearly 2.3% of the overall geographical area and approximately 10.7% of the overall livestock population of the world. Although considered a top milk producer, Indian livestock are generally considered less productive. India has an average productivity of 1538kg/yr, which is less than the global average of 2238 kg/yr, mainly due to the state of malnutrition or under nutrition of livestock. To satisfy the needs of the ever-growing population, the current milk production of 132 million tonnes (mt) had to be increased to 160 mt by 2020. To achieve this, green and dry fodder quantities of 825 mt and 494 mtare needed, and 54 mt of concentrates is required (Vijay *et al.,* 2018). However, at present country faces a net deficit of green and dry fodder (Singh *et al.,* 2022). To meet the green and dryfodder requirements of animals throughout the year, cultivation of perennial grasses (Bajranapier hybrid grass) in forage-based cropping sequences has become popular among dairy farmers in India (Singh *et al.,* 2002). It is gaining importance as they provide a year-round supply of fodder to cattle. However, issues with grasses such as Napier hybrid grass require high planting material and water. This can be overcome by adopting single budded setts with established treatment and microirrigation systems (Varshini and Jayanthi, 2019). Hence, the present work aimed to study the different crop establishment methods and irrigation methods in the present investigation to maximize the water use efficiency, water productivity and green and dry fodder yield of Bajranapier hybrid grass.

MATERIALS AND METHODS

A field experiment to study the influence of crop establishment and irrigation methods on water use studies on bajranapier hybrid grass CO (BN) 5 which is an interspecific hybrid between Fodder Cumbu IP 20594 (*Pennisetum glaucum*) and Napier grass FD 437 (*P. Purpureum Schumach*) was carried out during Field No. 75 in the Eastern block ofthe Department of Agronomy, Tamil Nadu Agricultural University-Coimbatore, in September 2018-2019. A strip plot design with three replications was used. Irrigation methods were imposed in the main plot *viz.,* M_1: Surface irrigation, M_2: Surface drip irrigation, M_3: Subsurface drip irrigation, M_4 : Micro sprinkler irrigation and crop establishment methods in sub plot *viz.,* S_1: Vertical planting of setts with sett treatment, S_2: Horizontal planting of setts with sett treatment, S_3: Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Vertical planting of two budded setts. The settling treatment adopted for the study was 12 hours of water soaking followed by 24 hours of incubation. Treatments S_1 to S_4 were adapted with single bud setts. For the main plot, irrigation scheduling for surface irrigation was performed based on an IW/CPE ratioof 0.80, *i.e.,* cumulative pan evaporation. For microirrigation systems, irrigation was given once every three days based on 100% pan evaporation.

Water use studies

Observations of water use efficiency, water productivity (t/m^3) and economic water productivity were calculated based on the standard formula.

Water Use Efficiency

WUE (t/ha/cm) = Economic yield (t/ha) / Total quantity of water applied (cm) ..... (1)

(Chai *et al.,*2014)

Water productivity (t/m^3)

It is expressed as the quantity of water required per tonnes of green fodder produced.

Water productivity (t/m^3) = Yield (t) /Volume of water used (m^3) x 100 ….(2)

Economic water productivity

Economic water productivity is a function of total water consumed and gross return obtained by the crop and expressed in ₹/ha/mm.

Water productivity = Gross return (₹/ha) /Total water consumed (mm) …..(3)

(Cetin and Kara, 2019).

Estimation of green and dry fodder yield

For green fodder yield, Bajranapier hybrid grass in the net plot area of each treatment was cut close to ground level, and the fresh weight was recorded and expressed as green fodder yield in t/ha. Furthermore, a weighed representative sample (of green forage) was collected from each treatment and dried in an oven at 70°C to obtain aconstant weight. From the dry weight ofthe sample, the total dry fodder yield was calculated and expressed as t/ha.

Postharvest available nutrients analysis

To estimate postharvest available nutrients, soil samples before planting and after each harvest from the experimental plots were drawn at a 0-30 cm depth. The samples were then air dried, ground to pass through a sieve of size 2 mm and then subjected to chemical analysis of N, P and K. The mean values were calculated and expressed as kg/ha.

Chemical Properties	Methods adopted
Nitrogen (kg/ha)	Alkaline permanganate method (Subbaiah and Asija, 1956)
Phosphorus (kg/ha)	Olsen's method (Olsen *et al.,* 1954)
Potassium (kg/ha)	Neutral normal ammonium acetate method (Stanford and English, 1949)

Data analysis

The statistical analysis was performed using the statistical method and strip plot design. Wherever the results were significant, the critical difference (CD) at the 5% level of significance was determined as given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Water use efficiency

Significant variation was observed by both irrigation methods and crop establishment methods (Table 1). Subsurface drip irrigation (M_3) resulted in the highest WUE of 23.74 t/ha/mm among the irrigation methods. This can be attributed to the uniform distribution of irrigation water as well as the lower evaporation from the soil surface, and the easy availability of water and nutrients within the root zone can also be a contributing factor. Furthermore, Ayars *et al*. (1999) stated that evaporation from subsurface drip irrigation was very minimal, and therefore transpiration was increased, which improved stomatal opening and photosynthesis. This, in turn, increased the yield and WUE by means of utilization of available water and nutrients that were supplied at regular intervals effectively throughout the crop. Sathiyaraj (2017) also concluded thata continuous moisture supply under subsurface drip irrigation led to efficient moisture utilization with less water loss, thereby increasing water use efficiency.In addition to this, Manikandan and Thiyagarajan (2021) found that subsurface drip irrigation with 60 per cent pan evaporation recorded higher WUE (113 kg/ha mm) in sugarcane which is mainly due to efficient utilization of available water and nutrients that were supplied at even intervals throughout the crop period to meet the crop needs that brings in the increased yield.

A significantly lower WUE of 15.10 t/ha/mm was registered with surface irrigation (M_1). Even with a higher total water requirement, this lower yield may be caused by high evaporative and percolation losses. These results are in line with the findings of Hassanli *et al.* (2009), who stated that the low water use efficiency with surface irrigation is mainly due to the high conveyance loss. This, in turn, resulted in reduced yield and thereby less water use efficiency. The lack of sufficient moisture content in roots' area and the exposure of the plant to water stress is reflected in the processes of cell expansion and division, and in the processes of decreased length stem and leaf growth, and the area of carbon assimilation as well as leaf area and leaf area index decrease which resulted in decrease in water use efficiency in surface irrigation (Thamer *et al.,* 2021)

Among crop establishment methods, a significantly higher WUE of 21.47 t/ha/mm was observed with horizontal planting of setts with settling treatment (S_2). This may be the early and synchronized emergence, which inturnly causes more leaf area and the development of anearly canopy. Furthermore, the better ground cover provided by this treatment may reduce the overall evaporation in the soil, thus saving adequate water for transpiration. In addition, early emergence may have also caused vigorous plant growth as well as deeper and extensive root systems capable of extracting water efficiently, even under lower irrigation regimes. This statement is further supported by Ali *et al*. (2013), who reported that wheat seed soaked in tap water for 12 hours (on-farm priming) increased water use efficiency. Subsequently, Arun *et al.* (2017) also reported that the sett treatment increased the water use efficiency compared with the control due to higher productive tillers with improved yieldof summer cowpea.

Significantly, a lower WUE of 17.38 t/ha/mm was registered with vertical planting of setts without sett treatment (S_3). This might be due to the poor plant population. The results of the interaction effect revealed that crop establishment and irrigation methods showed non-significant differences in water use efficiency. Lower fodder yield with higher loss of water. This was further confirmed by the findings of Meena *et al.* (2013) in wheat by stating that the interactive effect of different seed priming techniques along with seeding at sub optimal soil moisture level is an efficient technique for enhancing water productivity.

On water productivity and economic water productivity (Fig. 1.), subsurface drip irrigation (M_3) recorded higher water productivity (0.024 t/m^{3}) and economic water productivity (474.78 ₹/ha/mm). This is mainly because of the better utilization of moisture in subsurface and surface drip irrigation, and the yield was increased, leading to high water productivity. These results corroborate Shelke *et al*. (1999), who reported that the increased water productivity was mainly due to the application of water and nutrients near the root zone, reducing water percolation and nutrient leaching losses, leading to increased water percolation and nutrient leaching losses higher green and dry fodder yields with higher economic value.This is further supported by

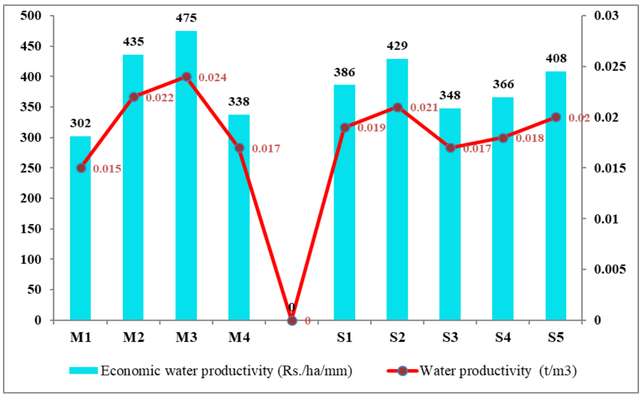

Fig. 1. *Effects of crop establishment and microirrigation methods on water and economic water productivity (M_1:Surface irrigation, M_2: Surface drip irrigation, M_3: Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Verticalplanting of two budded setts.*

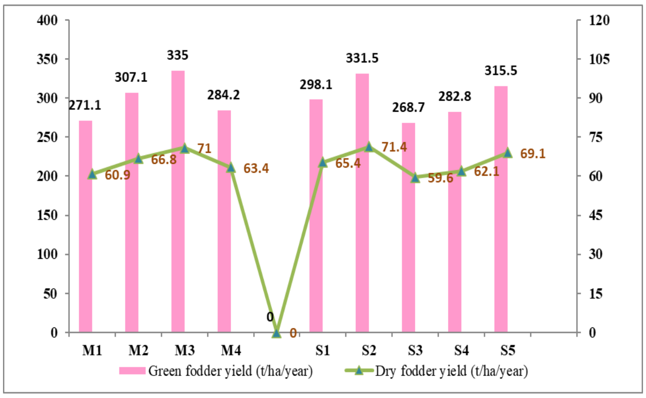

Fig. 2. *Effects of micro irrigation and crop establishment methods on green and dry fodder yields (t/ha/year) M_1:Surface irrigation, M_2: Surface drip irrigation, M_3 : Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Verticalplanting of two budded setts.*

Parthasarathi *et al.* (2016), who stated that surface drip irrigation resulted in higher yield and water productivity by effective utilization of waterin rice. Wang *et al.* (2021) explored this in their research by concluding that subsurface drip irrigation increased water productivity in alfalfa by reduced water loss. Lower water productivity (0.015 t/m^3) and economic water productivity (302.07 ₹/ha/mm) were observed with surface irrigation (M_1).

Among the crop establishment methods, higher water productivity (0.021 t/m$^{3)}$ and economic water productivity (429.43 ₹/ha/mm) were observed with horizontal planting with settling treatment (S_2). In horizontal planting with settling treatment, settings sprouted sooner than in vertical planting without settling treatment. Earlier sprouted setts and synchronized field emergence caused a large leaf area, early canopy development anda higher number of tillers. Furthermore, the presence of better ground cover minimizes the rate of evaporation from the soil, thus providing sufficient water for transpiration. Meena *et al.* (2013) in wheat and Rehman *et al.* (2015) in rice further expressed that a higher root volume improved the uptake of water and nutrients, thus increasing the yield and thereby water productivity. This might be due to delayed sprouting and establishment, poor population and reduced root volume, which decreased the water and nutrient uptake, resulting in lower yield and thereby reduced water productivity. Similar findings are reported by Roja *et al.* (2017). In the present study, lower water productivity (0.017 t/m^3)and economic water productivity (347.61 ₹/ha/mm) were registered with the vertical planting of setts without settling treatment (S_3). The interaction between irrigation methods and crop establishment, higher water productivity and economic water productivity was registered on subsurface drip irrigation with horizontal planting with sett treatment (M_3S_2).

Green and dry fodder yields

During the investigation, green fodder yield differed significantly due to irrigation methods and crop establishment methods (Fig. 2). With respect to irrigation methods, subsur-

Table 1. Effects of micro irrigation and crop establishment methods on water use efficiency (t/ha/mm)

Treatments	Water Use Efficiency (t/ha/mm)					Mean
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	
M_1	15.00	16.67	13.50	14.39	15.96	15.10
M_2	21.57	24.14	20.00	20.37	22.75	21.77
M_3	23.87	26.52	20.51	22.49	25.31	23.74
M_4	16.76	18.56	15.52	15.93	17.68	16.89
Mean	19.30	21.47	17.38	18.29	20.43	
	M	S	M at S	S at M		
Sed	0.51	0.59	1.17	1.18		
CD (P = 0.05)	1.24	1.20	NS	NS		

M_1:Surface irrigation, M_2: Surface drip irrigation, M_3 : Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4:

Table 2. Effects of micro irrigation and crop establishment methods on the postharvest soil available nitrogen (kg/ha) of Bajranapier hybrid grass

Treatments	Postharvest soil available nitrogen (kg/ha)					Mean
	S_1	**S_2**	**S_3**	**S_4**	**S_5**	
M_1	173.0	155.8	187.7	181.2	163.9	172.3
M_2	150.5	140.3	169.5	157.9	144.0	152.4
M_3	140.9	137.3	154.8	152.6	139.5	145.0
M_4	155.8	141.0	176.3	170.3	149.4	158.6
Mean	155.0	143.6	172.1	165.5	149.2	
	M	S	M at S	S at M		
SEd	3.8	4.9	9.5	9.8		
CD (P = 0.05)	9.3	9.9	NS	NS		

M_1:Surface irrigation, M_2: Surface drip irrigation, M_3 : Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Verticalplanting of two budded setts

Table 3. Effects of micro irrigation and crop establishment methods on postharvest soil available phosphorus (kg/ha) of Bajranapier hybrid grass

Treatments	Postharvest soil available phosphorus (kg/ha)					Mean
	S_1	S_2	S_3	S_4	S_5	
M_1	22.9	17.4	26.1	26.1	18.5	22.2
M_2	19.9	16.4	21.8	21.7	17.1	19.4
M_3	18.0	15.0	20.5	19.2	15.4	17.6
M_4	21.6	16.8	24.8	22.4	17.7	20.7
Mean	20.6	16.4	23.3	22.4	17.2	
	M	S	M at S	S at M		
SEd	0.5	0.6	1.2	1.1		
CD (P = 0.05)	1.3	1.2	NS	NS		

M_1:Surface irrigation, M_2: Surface drip irrigation, M_3 : Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Vertical planting of two budded setts.

Table 4. Effect of microirrigation and crop establishment methods on postharvest soil available potassium (kg/ha) of Bajranapier hybrid grass

Treatments	Postharvest soil available potassium (kg/ha)					Mean
	S_1	S_2	S_3	S_4	S_5	
M_1	607.3	516.6	645.8	622.8	565.0	591.5
M_2	563.0	490.5	592.7	574.6	528.0	549.7
M_3	487.2	433.9	575.3	528.7	471.2	499.3
M_4	565.9	495.9	605.2	579.7	530.7	555.5
Mean	555.8	484.2	604.8	576.4	523.7	
	M	S	M at S	S at M		
SEd	10.2	15.1	28.9	30.2		
CD (P = 0.05)	24.9	30.8	NS	NS		

M_1:Surface irrigation, M_2: Surface drip irrigation, M_3 : Subsurface drip irrigation, M_4: Micro sprinkler irrigation; S_1: Vertical planting of setts with sett treatment,S_2: Horizontal planting of setts with sett treatment, S_3:Vertical planting of setts without sett treatment, S_4: Horizontal planting of setts without sett treatment, S_5: Vertical planting of two budded setts

face drip irrigation (M_3) produced significantly higher green (335.0 t/ha/year) and dry fodder (71 t/ha/year) yields. This might be because of the availability of sufficient water near the root zone, which caused the growth parameters to be enhanced. Patel *et al*. (1990) and Abu-Suwar and Bakri (2009) found similar results in alfalfa, stating that subsurface drip increased plant length and the number of branches. This is further supported by Cao *et al.*(2020), who in their study confirmed that sub surface drip irrigation method increased the hay yield of alfalfa. Lower green (271.1 t/ha/year) and dry (60.9 t/ha/year) fodder yields were observed under surface irrigation (M_1).

Among the crop establishment methods, horizontal planting of setts with settling treatment (S_2) recorded higher green (331.5 t/ha/year) and dry (71.4 t/ha/year) fodder yields. The highest green and dry fodder yields in horizontal planting might be associated with early crop establishment and better root system development, which helped in the efficient absorption of nutrients and moisture from the soil, further inducing profused vegetative growth, plant height and tillers that led to higher greenand dry fodder yields. Similar findings were also reported by Lewthaite and Triggs (2009), who reported that horizontally planted cuttings developed adventitious roots at the callus tissues at the cut end with ample space for full expansion of roots, thus increasing the yieldof sweet potato. In the present study, a significantly lower green (268.7 t/ha/year) and dry (59.6 t/ha/year) fodder yield was observed with vertical planting of setts without settling treatment (S_3). The results of the interaction effect revealed that both the crop establishment and irrigation methods showed non-significant differences in green and dry fodder yields. These results are further supported by Ghassemi-Golezani *et al.* (2011) in soyabean over the interaction effect of irrigation and seed priming.

Postharvest soil available nutrients

On postharvest available soil nutrients (Table 2-4), higher soil available nitrogen(172.3 kg/ha), phosphorus (22.2 kg/ha) and potassium (591.5 kg/ha) were observed with surface irrigation (M_1).The fertilizer applied on the soil surface was not fully utilized by the crops, which inturnly increased the nutrient content in the soil. Significantly lower soil nitrogen (145.0 kg/ha), phosphorus (17.6 kg/ha) and potassium (499.3 kg/ha) were recorded with subsurface drip irrigation (M_3).

Vertical planting of setts without settling treatment (S_3) recorded higher soil available nitrogen (172.1 kg/ha), phosphorus (23.3 kg/ha) and potassium (604.8 kg/ha).This is mainly because of reduced plant root growth, and tillers left the soil nutrients in the soil, which increased soil available nutrients. Significantly lower (0.05 %) soil available nitrogen (143.6 kg/ha), phosphorus (16.4 kg/ha) and potassium (484.2 kg/ha) were observed with horizontal planting of setts with sett treatment (S_2). The interaction between irrigation methods and crop establishment methods showed a non-significant difference in postharvest soil available nutrients.

Conclusion

The study concluded that to achieve higher water use efficiency, water productivity and green fodder yield, subsurface drip irrigation and horizontal planting of single budded setts are recommended for bajranapier hybrid grass. Adopting single budded setts with settling treatments cansavedupto50 percent of planting material and 25 percent of water. This in turn increases efficiency of fodder cultivation and reduces the cost of cultivation, thereby encouraging farmers to cultivate the fodder, which in turnhelps to increases the production of quality fodder that is essential to address the growing threat of fodder deficit.

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Abu-Suwar, A. O. & Bakri, E (2009). Effect of water quality and weeding on yield and quality of three alfalfa (*Medicago Sativa,* L.) cultivars. *Australian Journal of Crop Science* 3 (6), 315-321.
2. Ali, H., Iqbal, N., Shahzad, A. N., Sarwar, N., Ahmad, S. & Mehmood, A. (2013). Seed priming improves irrigation water use efficiency, yield, and yield components of late-sown wheat under limited water conditions. *Turkish Journal of Agriculture and Forestry*, 37 (5), 534-544.Doi:10.3906/tar-1207-70
3. Arun, M. N., Hebbar, S. S., Bhanuprakas, K. & Senthivel, T. (2017). Seed priming improves irrigation water use efficiency, yield and yield components of summer cowpea under limited water conditions. *Legume Research-An International Journal,* 40 (5), 864-871.DOI:10.18805/LR-3785
4. Ayars, J. E., Phene, C. J., Hutmacher, R. B., Davis, K. R., Schoneman, R. A., Vail, S. S. & Mead. R. M. (1999). Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. *Agricultural water management*, 42 (1), 1-27.https://doi.org/10.1016/S0378-3774(99)00025-6.
5. Cao, X., Feng, Y., Li, H., Zheng, H., Wang, J. & Tong, C. (2021). Effects of subsurface drip irrigation on water consumption and yields of alfalfa under different water and fertilizer conditions. *Journal of Sensors*, 2021.https://doi.org/10.1155/2021/6617437.
6. Çetin, O. & Kara, A. (2019). Assesment of water productivity using different drip irrigation systems for cotton. *Agricultural Water Management,* 223, 105693.https://doi.org/10.1016/j.agwat.2019.105693.
7. Chai, Q., Gan, Y., Turner, N. C., Zhang, R. Z., Yang, C., Niu, Y. & Siddique, K. H. (2014). Water-saving innovations in Chinese agriculture. *Advances in Agronomy,* 126, 149-201.https://doi.org/10.1016/B978-0-12-800132-5.00002-X
8. Ghassemi-Golezani, K., Farshbaf-Jafari, S. & Shafagh-Kolvanagh, J. (2011). Seed priming and field performance of soybean (*Glycine max*, L.) in response to water limitation. *Notulae Botanicae Horti Agro botanici Cluj-Napoca,* 39 (2), 186-189.DOI: https://doi.org/10.15835/nbha3926122.
9. Gomez, K. A. & Gomez, A. A. (1984). Analysis of data from a series of experiments. *Statistical Procedures for Agricultural Research.* 2nd ed. New York: J. Wiley, 316-356.
10. Hassanli, A. M., Ebrahimizadeh, M. A. & Beecham. S (2009). The effects of irrigation methods with effluent and irrigation scheduling on water use efficiency and corn yields in an arid region. *Agricultural Water Management*, 96 (1), 93-99.https://doi.org/10.1016/j.agwat.2008.07.004.
11. Lewthwaite, S. L. & Triggs, C. M. (2009). Preliminary study of the spatial distribution of sweet potato storage roots. *Agronomy New Zealand,* 39, 111-112.
12. Meena, R. P., Sendhil, R., Tripathi, S. C., Chander, S., Chhokar, R. S. & Sharma, R. K. (2013).Hydropriming of seed improves the water use efficiency, grain yield and net economic return of wheat under different moisture regimes. *SAARC Journal of Agriculture,* 11 (2), 149-159.DOI: https://doi.org/10.3329/sja.v11i2.18410
13. Manikandan, M., & Thiyagarajan, G. (2021). Study on Irrigation and Fertigation Scheduling for Sustainable Sugarcane Initiative (SSI) through Subsurface Drip Irrigation. *Cutting-edge Research in Agricultural Sciences,* 13, 55-61.DOI: 10.9734/bpi/cras/v13/11364D
14. Olsen, R. R., Cole, C. L.,Watnabe, F. S. & Dean. D. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ.:939.
15. Parthasarathi, T., Vanitha, K., Mohandass, S., Vered, E., Meenakshi, V., Selvakumar, D. & Lazarovitch, N. (2016). Effect of drip irrigation on growth, physiology, yield and water use of rice. *Journal of Agricultural Science,* 9 (1), 154-163.Doi:10.5539/jas.v9n1p154
16. Patel, J. R., Patel, C., Sadhu, A. C. & Patel, B. G. (1990). Response of lucerne genotypes to phosphorus and potash. *Indian Journal of Agronomy,* 35 (3), 307-308.
17. Rehman, H., Kamran, M., Basra, S. M. A., Afzal, I. & Farooq, M. (2015). Influence of seed priming on performance and water productivity of direct seeded rice in alternatingwetting and drying. *Rice Science,* 22 (4), 189-196.http://dx.doi.org/10.1016/j.rsci.2015.03.001.
18. Roja, M, Kumar, K. S., Ramulu, V. & Satish, C. (2017). Water productivity of *rabi* maize influenced by different

drip irrigation treatments. *International Journal of Agriculture Sciences,* 9 (34), 4515-4517

19. Sathiyaraj, M. (2017). Irrigation regimes and fertigation levels on sugarcane under subsurface drip fertigation. *International Journal of Current Microbiology and Applied Sciences,* 6 (11), 3674-3684.DOI: https://doi.org/10.20546/ijcmas.2017.611.430.
20. Shelke, D. K., Vaisnava, V. S., Jadhav, G. S., &Oza, S. R. (1999). Optimizationof irrigation water and nitrogen to cotton through drip irrigation system. *Indian Journal of Agronomy,* 44 (3), 629 - 633.
21. Singh, D. N., Bohra, J. S., Tyagi, V., Singh, T., Banjara, T. R., & Gupta, G. (2022). A review of India's fodder production status and opportunities. *Grass and Forage Science*, 77(1), 1-10. https://doi.org/10.1111/gfs.12561
22. Singh, D., Singh,V. &Joshi, Y. P.(2002). Herbage yield and yield attributes of napier bajra hybrid at different cuts as affected by cutting intervals and varying level of nitrogen. *Forage Research,* 27 (4):267-272.
23. Stanford, S. & English, L.(1949). Use of flame photometer in rapid soil tests for K and Ca. *Agronomy Journal,* 41, 446-447.
24. Subbaiah, B. V. & Asija, G. L.(1956). Rapid procedure for estimation of available nitrogen in soil. *Current Science,* 25, 259-260.
25. Thamer, T., Nassif, N., Almaeini, A. & Al-Ansari, N. (2021). Impact of evaluation of different irrigation methods with sensor system on water consumptive use and water use efficiency for maize yield. *Journal of Water Resource and Protection*, 13(11), 835-854.DOI: 10.4236/jwarp.2021.1311045.
26. Varshini S. V. & Jayanthi C. (2019). Effect of crop establishment on the performance of bajranapier hybrid grass CO (BN) 5. *Madras Agricultural Journal*, 106, 590-593.Doi:10.29321/MAJ 2019.000316
27. Vijay, D., Gupta, C. K. & Malaviya, D. R. (2018). Innovative technologies for quality seed production and vegetative multiplication in forage grasses. *Current Science*, 114 (1), 148. https://doi.org/10.18520/cs%2Fv114%2Fi01%2F148-154.
28. Wang, Y., Liu, C., Cui, P. & Su, D. (2021). Effects of partial root-zone drying on alfalfa growth, yield and quality under subsurface drip irrigation. *Agricultural Water Management,* 245, 106608.https://doi.org/10.1016/j.agwat.2020.106608.