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Carbon isotope discrimination and water use efficiency relationship in fodder cowpea varieties

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Abstract: *A field experiment was conducted in the upland area of the Instructional Farm of College of Agriculture, Vellayani, Trivandrum during the summer season of 2012 to identify drought tolerant varieties of fodder cowpea in open and in partial shade. The investigation was conducted as two separate experiments, one in open and another in shaded situation (25-35 per cent shade). The design was laid out in split plot with four replications. The main plot factor included four soil moisture stress levels, M_1: presowing irrigation + life saving irrigation; M_2 : presowing irrigation + irrigation at IW/CPE ratio 0.4; M_3 : presowing irrigation + irrigation at IW/CPE ratio 0.6; M_4 : presowing irrigation + irrigation at IW/CPE ratio 0.8. The sub plot factor included five fodder cowpea varieties, V_1-UPC-618, V_2-UPC-622, V_3-Bundel Lobia-1, V_4-COFC-8 and V_5-CO-5. Field water use efficiency and carbon isotope discrimination ratio were calculated. Stable isotope discrimination values were significantly lower at IW/CPE ratio of 0.8 in open and 0.6 in shade. Water use efficiency was negatively correlated to stable isotope discrimination values. COFC- 8 recorded significantly lower discrimination values and higher water use efficiency in both open and shade.*

Key words: *discrimination, irrigation, varieties, water use efficiency*

INTRODUCTION

Fodder cowpea (*Vigna unguiculata* L. Walp) is a legume inherently more tolerant to drought than other fodder legumes (Fatokun *et al.*, 2009) and considered as a crop capable of improving sustainability of livestock production through its contribution in improving seasonal fodder productivity and nutritive value. It has shade tolerance, quick growth and rapid ground covering ability. Summer cowpea irrigated according to a schedule based on IW/CPE ratio of 0.8 recorded the maximum dry matter production (Subramaniam *et al.*, 1993) and plant height (Kher *et al.*, 1994). Fodder cowpea varieties CO-5, COFC- 8, UPC - 618, UPC-622, Bundel Lobia-1 are high yielding and suitable for cultivation in Kerala (Rajasree 1994; Lakshmi *et al.*, 2007; Gayathri, 2010). It is the most widely cultivated fodder legume in areas where rainfall is scanty and soils are relatively infertile. Most households that keep livestock raise fodder cowpea as an intercrop with other crops and fodder cowpea forms an integral component of crop livestock farming system (Singh and Tarawali, 2011).

Water stress affects photosynthesis directly and indirectly and consequently dry matter production and its allocation to various plant organs. Water use efficiency is the production of moles of carbon gained in photosynthesis in exchange for water used in transpiration. Water use efficiency is an important trait for improving drought tolerance in fodder cowpea, WUE would help save considerable amount of irrigation water. Carbon isotope discrimination (CID), one technique used to determine the efficiency of water use, was positively correlated with forage yield and maturity. Carbon isotope discrimination in plant leaves has been negatively associated with water use efficiency (Fening *et al.*, 2009). Therefore, an assessment of the selection response of CID and its relationship to plant water status is needed. It is in this context that this study was undertaken to assess the performance of five fodder cowpea varieties and the relationship of CID and WUE under varying soil

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moisture regimes both in open and shaded situation during the lean dry months.

MATERIALS AND METHODS

A field experiment was conducted in the upland area of the Instructional Farm of College of Agriculture, Vellayani, Trivandrum during the summer season of 2012. The investigation was conducted as two separate experiments, one in open and another in shaded situation (25-35 per cent shade). The design was laid out in split plot with four replications. The main plot factor included four soil moisture stress levels, M_1: presowing irrigation + life saving irrigation; M_2 :presowing irrigation + irrigation at IW/CPE ratio 0.4; M_3 : presowing irrigation + irrigation at IW/CPE ratio 0.6; M_4 : presowing irrigation + irrigation at IW/CPE ratio 0.8. The sub plot factor included five fodder cowpea varieties, V_1-UPC-618, V_2-UPC-622, V_3-Bundel Lobia-1, V_4-COFC-8 and V_5-CO-5. Presowing irrigation was given to all the plots uniformly upto 10 days after sowing for germination and establishment. Thereafter irrigation was given as per the treatments based on the evaporation data and depth of irrigation. . The quantity of water applied to each plot in one irrigation was 600 litres. FYM @ 10 t ha^{-1} was applied uniformly to all the plots at the time of final preparation of land. Entire dose of phosphorus was given as basal @ 30 kg ha^{-1}. Nitrogen @ 40 kg ha^{-1} and potassium @ 30 kg ha^{-1} were given in two equal splits, one as basal and one after one month of sowing. The fodder cowpea varieties as per treatments were sown at a spacing of 30 x 15cm @ 2 seeds $hole^{-1}$ on 14th January 2012 both in open as well as in shade (25-35 per cent). The carbon isotope discrimination ratio (CID) is $_{13}C$ / $_{12}C$ was determined for calculating the isotope discrimination. The third fully opened leaf of ten sample plants were collected and oven dried and ground and the samples were sent to the National Facility Department of Crop Physiology, UAS Bangalore for determining the CID ratio using IRMS (Isotope Ratio Mass Spectrophotometer). Field water use efficiency was calculated by dividing the economical crop yield by the total quantity of water applied in the field (WR) and expressed in kg $ha^{-1}mm^{-1}$.

RESULTS AND DISCUSSION

The results of the effect of soil moisture stress levels and varieties on stable isotope discrimination of fodder cowpea in open and shaded condition are presented in Table 1 & 2. Both the treatments had significant impact on stable isotope discrimination of fodder cowpea in both conditions. In open condition, significantly lower carbon isotope discrimination ratio (CID) (18.99) was recorded by irrigating at IW/CPE ratio of 0.4 (M_2), followed by irrigation at IW/CPE ratio 0.6(M_3) (19.14) which was on par with IW/CPE ratio of 0.8(M_4) (19.18). Among the varieties COFC-8 (V_4) recorded significantly lower CID ratio (17.98) followed by UPC-622 (V_2) (19.34) which was on par with Bundel Lobia-1 (V_3) (19.53). The interaction effect was non-significant. Under 25-35 per cent shaded condition both the treatments had significant influence on CID ratio of fodder cowpea. Significantly lower CID ratio (20.40) was recorded by irrigation at IW/CPE ratio of 0.6 (M_3) followed by irrigation at IW/CPE ratio of 0.8 (M_4) (21.91) which was on par with irrigation at IW/CPE ratio of 0.4 (M_2) (21.91). Among the varieties COFC-8(V_4) recorded significantly lower CID ratio (20.46) which was on par with UPC-618(V_1) (20.84). The interaction effect was non-significant. Carbon isotope discrimination tends to decrease in a linear manner from the highest to lowest water level (Johnson *et al.*, 2003). The isotopic ratio of $_{13}C$ to $_{12}C$ in plant tissue is less than the isotopic ratio of $_{13}C$ to $_{12}C$ in the atmosphere, indicating that plants discriminate against $_{13}C$ during photosynthesis. The isotopic ratio of $_{13}C$ to $_{12}C$ in C_3 plants varies mainly due to discrimination during diffusion and enzymatic process (Farquhar *et al.*, 1989). Decreasing soil moisture during dry periods decreased leaf conductance and intercellular CO_2 levels, which in turn lowered carbon isotope discrimination (Farquhar and Richards, 1984; Johnson *et al.*, 1990). Considerable variations in carbon isotope discrimination were reported in forage grasses and legumes under different soil moisture stress levels by Sima *et al.* (2010). Varieties also showed significant influence on stable isotope discrimination both in open and shade. Among the varieties, COFC-8 recorded lower carbon isotope discrimination in both the conditions. The rate of diffusion of $_{13}C$ across the stomatal pore in this variety is more compared to other varieties, which leads to higher water use efficiency. Similar results were also reported by Sima *et al.* (2010) in *Festuca pratensis* and *Lolium corniculatus*

The effects of treatments are significant with respect to water use efficiency of fodder cowpea in open condition. Significantly higher water use efficiency (42.95 kg ha^{-1} mm^{-1}) was recorded by irrigation at IW/CPE ratio of 0.4 (M_2) which was on par with irrigation at IW/CPE ratio of 0.6 (M_3) (41.31 kg $ha^{-1}mm^{-1}$). This might be attributed to the strong sensitivity of cowpea stomata to water stress with

Table 1
Effect of soil moisture stress levels and varieties on stable isotope discrimination ($_{13}$C) and water use efficiency (WUE) of fodder cowpea

Treatments	*Stable isotope discrimination*		*Water use efficiency (kg ha^{-1}mm^{-1})*	
	Open	*Shade*	*Open*	*Shade*
Soil moisture stress levels (M)				
M_1- Life saving	20.19	22.50	36.55	17.00
M_2- IW/CPE = 0.4	18.99	21.91	42.95	20.07
M_3- IW/CPE = 0.6	19.14	20.40	41.31	21.65
M_4- IW/CPE = 0.8	19.18	21.91	37.14	17.31
SEm (±)	0.546	0.293	1.249	0.671
CD (0.05)	0.874	0.469	1.999	1.073
Varieties (V)				
V_1 - UPC 618	19.98	20.84	37.53	20.95
V_2 - UPC 622	19.34	21.28	41.64	18.63
V_3- Bundel lobia-1	19.53	21.63	40.26	18.21
V_4 - COFC -8	17.98	20.46	48.03	22.24
V_5 - CO-5	20.81	22.85	29.99	15.01
SEm (±)	0.344	0.356	1.460	0.545
CD (0.05)	0.49	0.506	2.076	0.775

Table 2
Interaction effect of soil moisture stress levels and varieties on stable isotope discrimination ($_{13}$C) and water use efficiency (WUE) of fodder cowpea

Treatments	*Stable isotope discrimination*		*Water use efficiency (kg ha^{-1}mm^{-1})*	
	Open	*Shade*	*Open*	*Shade*
M x V				
m_1v_1	20.71	22.20	34.33	18.49
m_1v_2	20.11	22.80	38.66	16.39
m_1v_3	20.15	22.33	37.27	16.70
m_1v_4	18.16	21.49	46.25	19.55
m_1v_5	21.83	23.72	26.26	13.88
m_2v_1	19.65	20.35	40.63	22.42
m_2v_2	19.94	20.17	42.75	19.37
m_2v_3	18.94	21.20	41.78	18.84
m_2v_4	17.31	20.11	53.23	23.78
m_2v_5	20.10	22.30	36.30	15.94
m_3v_1	19.43	19.62	40.72	23.92
m_3v_2	18.58	20.43	45.12	21.55
m_3v_3	19.29	20.79	41.64	20.68
m_3v_4	17.82	19.33	48.99	25.47
m_3v_5	20.6	21.84	30.68	16.65
m_4v_1	20.11	21.19	34.43	18.96
m_4v_2	19.74	21.73	40.01	17.23
m_4v_3	19.72	22.22	40.28	16.63
m_4v_4	18.61	20.91	43.64	20.16
m_4v_5	20.70	23.52	27.34	30.58
SEm (±)	0.344	0.356	1.460	0.545
CD (0.05)	NS	NS	NS	NS

reduction in photosynthetic capacity. Supporting results were recorded by Ahmed and Suliman (2010) in fodder cowpea genotypes. They attributed the effect of drought on WUE to stomatal closure, decreased transpiration and decreased leaf turgidity, which have consequences on photosynthesis. Similar results were reported by Volesky and Berger (2012) in warm season annual grasses and Hayatu and Mukhtar (2010) in fodder cowpea genotypes. Among the varieties, COFC-8 (V_4) recorded significantly higher WUE (48.03 kg ha^{-1} mm^{-1}) followed by UPC-622 (V_2) (41.64 kg ha^{-1} mm^{-1}). Significant variations among varieties were also recorded in open and partial shade. Among the varieties, COFC-8 recorded a higher WUE both in open and in partial shade. Isotope discrimination is inversely related to water use efficiency and COFC-8 had higher WUE and lower $_{13}$c. Hamidou *et al.* (2007) showed that stomatal closure is the common strategy used by cowpea genotypes to avoid dehydration. Considerable variations in WUE in fodder cowpea genotypes were reported by Hayatu and Mukhtar (2010). The interaction effect was non-significant. Under 25-35 per cent shade, significantly higher WUE (21.65 kg ha^{-1} mm^{-1}) was recorded by irrigation at IW/CPE ratio of 0.6 (M_3) followed by irrigation at IW/CPE ratio of 0.4 (M_2) (20.07 kg ha^{-1} mm^{-1}). Among the varieties, COFC-8 (V_4) recorded higher WUE of 22.24 kg ha^{-1}mm^{-1} followed by UPC-618 (V_1) (20.95 kg ha^{-1} mm^{-1}). The interaction effect was non-significant.

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