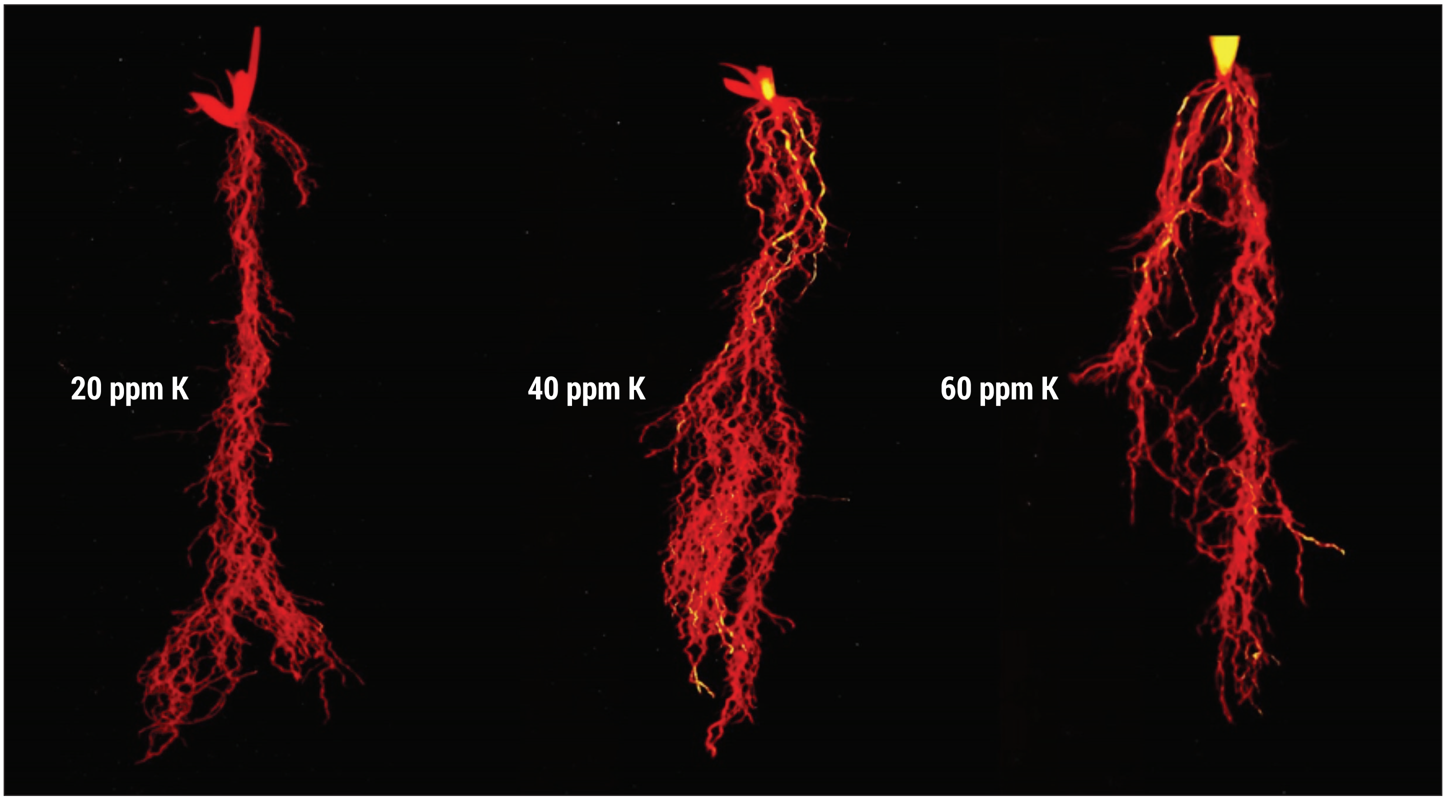
Revealing the Effects of Potassium on Rice Roots under Moisture Stress

By Kirti Bardhan, Dipika S. Patel, and Dhiraji P. Patel



Root system architecture of rice at 21 days after emergence under 20% FC (water limiting) receiving either 20, 40, or 60 ppm K.

Water availability is becoming the primary limiting factor for crop productivity in both developing and developed countries. In India, more than 60% area of arable land is in the arid and semi-arid region, which is characterized by long, dry seasons with inadequate and unpredictable rainfall. Rice is an important staple food crop of India predominantly grown under rainfed conditions and prevalence of continuous drought spells will have negative implications on sustainable rice production. Moreover, one-third of the world's rice is cultivated in rain-fed low lands, and 13% rice is grown in upland rainfed fields. Rice productivity has been reduced due to water stress and due to a burgeoning problem of climatic change, which will further aggravate farmers in the coming future. The identification of drought-tolerant traits coupled with drought mitigating, agronomic management practices has been a constant focus for research. One management approach is to increase the supply of K fertilizer to rice. It has a substantial role in alleviating drought effects by osmoregulation, stomatal regulation, and it can enhance photosynthesis, tissue water content, etc.

Plants have evolved diverse adaptation mechanisms for drought stress. Root architecture plasticity, relative change in each root trait under stress, can provide evidence for improved plant performance under moisture stress and is considered one of the mechanisms for mitigating drought

SUMMARY
The role of K in providing drought tolerance in the aerial parts of plants at the cellular, molecular, tissue, and organ level is well established compared to the plant root system. However, it is known that plants acquire soil water from deeper layers by modifying root architecture. The current study investigated the role of K in changing root architecture to facilitate more water acquisition as a mechanism to mitigate drought stress.

KEYWORDS:
Potassium; root architecture; drought stress

ABBREVIATIONS AND NOTES:
K = potassium; K_2SO_4 = potassium sulfate; FC = field capacity; ppm = parts per million

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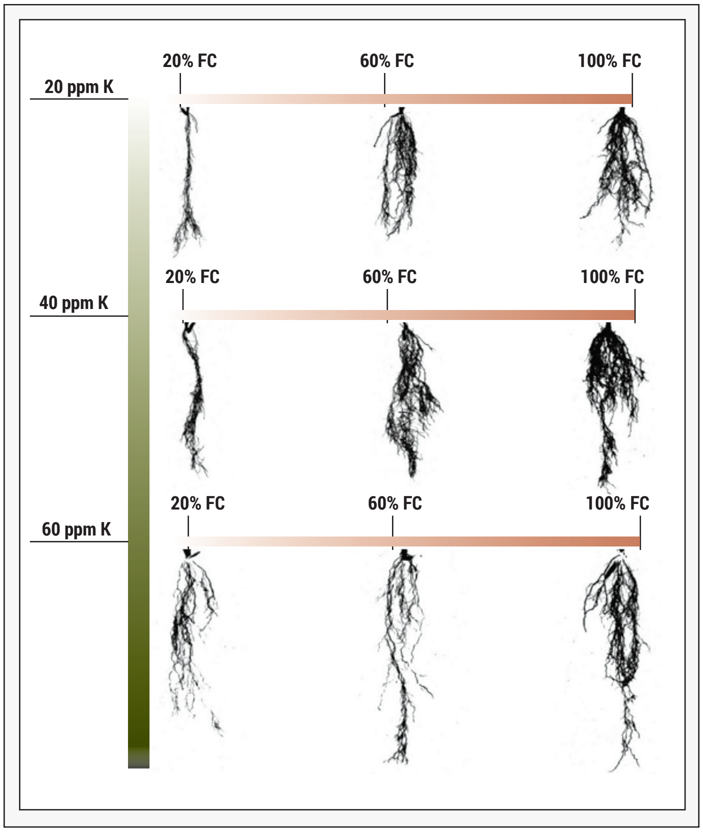

Figure 1. Image depicting the root system architecture of rice under different K concentrations and moisture levels at 21 days after emergence.

in crop plants, including rice. As plant roots are important in the sensing and acquisition of water and K along with other soil resources, and these factors also modulate root growth and architecture of the plant, it becomes crucial to know how changes in K nutrition may facilitate better water acquisition and drought tolerance.

Study Description

Ms. Dipika S. Patel addressed this question in her graduate research through a study on root architectural responses of rice seedling (variety NAUR-1) to K and moisture stress in a greenhouse at Navsari Agricultural University, Gujarat (India). The experiment was laid out in a complete randomized block design with nine treatment combinations and three replications, consisting of three levels each of K and soil moisture contents, or field capacities (FC). Rice seeds were sown in poly bags filled with a mixture of sand (800 g) and perlite (400 g). Moisture stress was imposed after seed emergence and seedlings were grown at 20% FC, 60% FC, and 100% FC. Average daily water loss was measured from four identical bags by weight and the daily water loss was replenished up to the desired FC. Three different types of nutrient solutions were prepared for replenishing the water amount. The nutrient solution was standard Yoshida solution (Yoshida et al., 1976) that was modified for the three different K concentrations. Periodically at 7, 14, and 21 days after emergence (DAE), treatment-wise seedling root

Table 1. Projected root area (mm^2) of rice seedling as influenced by various potassium and moisture stress treatments.

	---------- 21 Days after emergence ----------			
Treatments	20 ppm (K_1)	40 ppm (K_2)	60 ppm (K_3)	Mean (M)
(M_1) 100% FC	353	505	575	478
(M_2) 60% FC	244	326	351	307
(M_3) 20 % FC	172	229	252	217
Mean (K)	256	354	393	
	K	M	KxM	
S.Em ±	11	11	20	
CD (p=0.05)	34	34	57	
CV %	10			

images were scanned and analyzed by online Digital Imaging Root Traits (DIRT) platform (Das et al., 2015). Aboveground traits such as relative water content and growth parameters were also observed.

Potassium and Moisture Stress Interaction on Rice Root Architecture

Significant differences were observed in root projected area, average root density, maximum width of root system, root top angle, root bottom angle, root depth, and maximum width to depth ratio due to different soil K concentrations, moisture stress levels, and their interactions (**Figure 1**).

Projected root area of rice, as shown in (**Figure 2**), showed significant differences due to the interaction of moisture stress and K concentration (**Table 1**). At 100% FC, increasing K concentrations 20 to 60 ppm increased the projected root area by 62% (from 353 to 575 mm^2), while

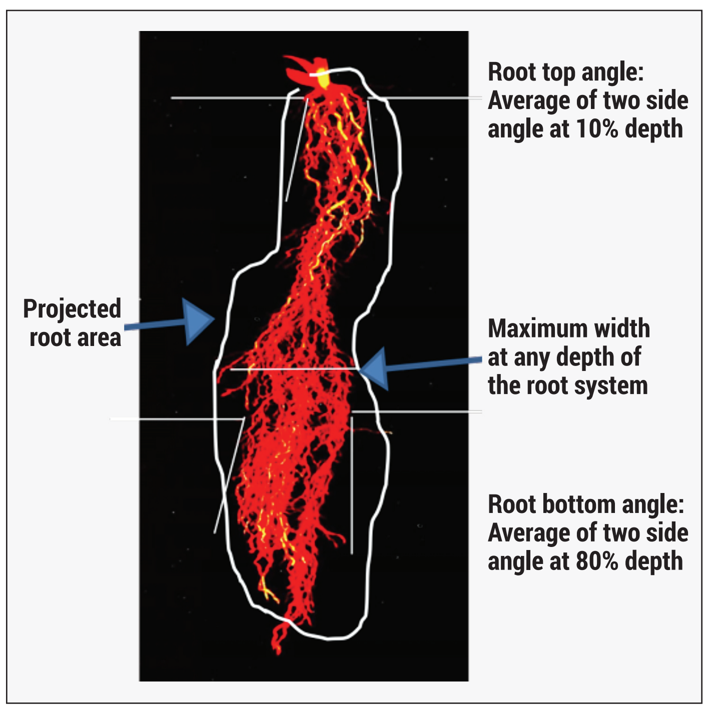

Figure 2. Picture depicting terminology of root architecture.

Table 2. Rooting depth skeleton (mm) of rice seedlings as influenced by various potassium and moisture stress treatments.

	- - - - - 21 Days after emergence - - - - -			
Treatments	20 ppm (K_1)	40 ppm (K_2)	60 ppm (K_3)	Mean (M)
(M_1) 100% FC	114	137	141	131
(M_2) 60% FC	111	156	170	146
(M_3) 20 % FC	110	159	175	148
Mean (K)	112	151	162	
	K	M	KxM	
S.Em ±	2.8	2.8	4.9	
CD (p=0.05)	8.4	8.4	14	
CV %		6.0		

at 20% FC the projected root area increased by 47% (from 172 to 252 mm²). On the other hand, increased moisture stress (20% FC) along with lower K concentration (20 ppm K) showed significant reduction in projected root area (172 mm²) over other two K concentrations (229 mm² at 40 ppm K and 252 mm² at 60 ppm K). Results further showed that the projected root area decreased by 55% with increasing moisture stress, while it increased by 53% with higher K concentration (**Table 1**), indicating that the root area of rice can be maintained by application of adequate K even if the rice crop is subjected to moisture stress.

Contrary to projected root area, the rooting depth increased with moisture stress and an encouraging effect of K was noticed both at 40 and 60 ppm K. The rooting depth was significantly increased from 137 to 159 mm at 40 ppm K, and 141 to 175 mm at 60 ppm K (**Table 2**), indicating that rice plants are able to absorb nutrients from deeper soil layers due to K induced progression in rooting depth despite subjected to moisture stress.

The study showed that moisture deficit decreased maximum width of the root system, while application of K at 60 ppm nullified the effect of moisture stress as significantly higher maximum width of the root system was observed at all the three levels of moisture stress (**Figure 3**). A similar trend on width of root system was also recorded at 20 ppm K as significantly higher maximum width of the root system was observed at 100% FC, which decreased progressively with increasing moisture stress.

Root top angle was measured between the 10% depth and horizontal soil line (**Figure 2**). A narrower root top angle was observed at 100% FC while broader root top angle was recorded in 20% FC (**Figure 4, top**). Availability of moisture and K, both were found to interact for regulation of the root top angle of rice seedlings. However, at 60% FC, root top angle of seedlings supplied with 40 and 60 ppm K were at par with each other. At 20% FC, root top angle from the seedlings supplied with higher K (60 ppm) was narrower,

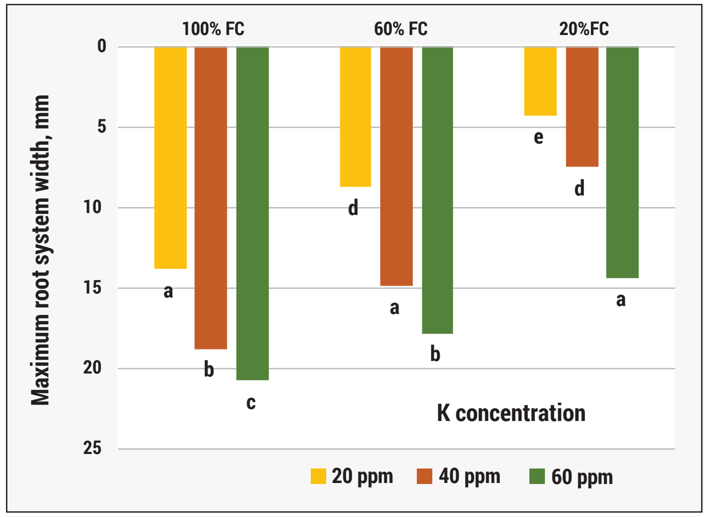

Figure 3. Effect of potassium and moisture availability on maximum width of root system of rice (NAUR-1) at 21 DAE. Any two bars having a common letter does not differ from each other at *p*=0.05.

and seedlings that were grown with low K (20 ppm) recorded a wider root top angle, indicating that with increasing moisture stress the interaction between moisture and K becomes more profound. Thus, it seems that higher concentration

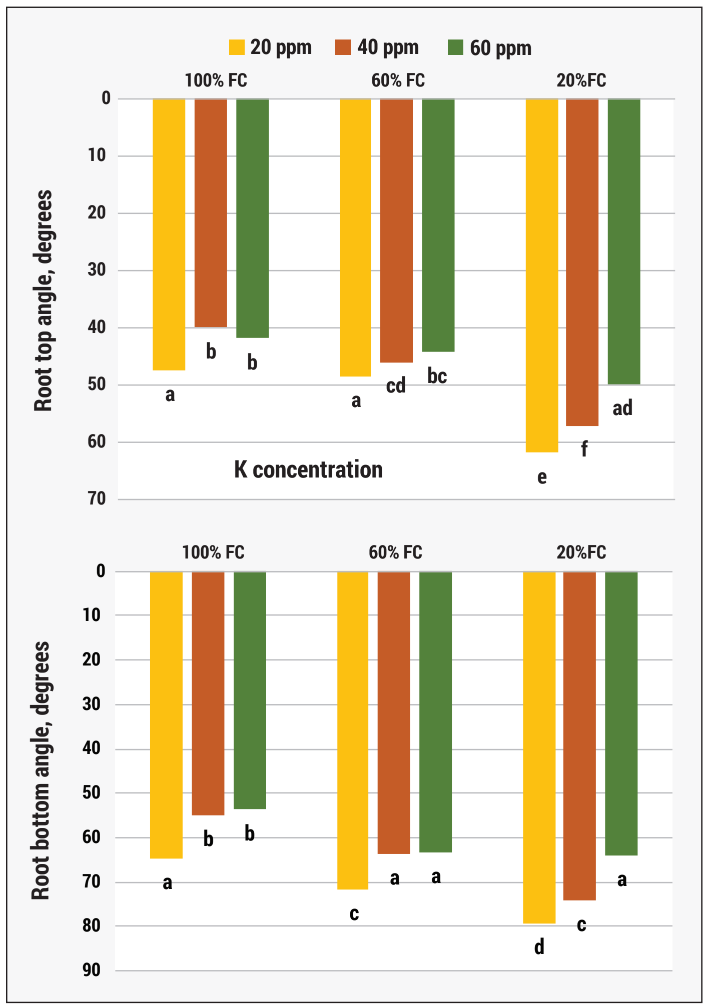

Figure 4. Effect of potassium and moisture availability on root top angle (top) and bottom angle (bottom) of rice (NAUR-1) at 21 DAE. Any two bars having a common letter does not differ from each other at *p*=0.05.

Figure 5. Comparative growth of rice seedlings under different potassium and moisture levels.

of K under moisture deficit condition, helped roots by resisting the effect of moisture stress on root top angle and restricted roots to become steeper under water limitation. These observations would help rice roots by increasing soil exploration area for efficient acquisition of other nutrients.

Root bottom angle was measured between the 80% depth and horizontal soil line (**Figure 2**). Under no moisture stress, significantly broader root bottom angle was observed in 20 ppm K while root bottom angle under 40 and 60 ppm K were at par with each other (**Figure 4, bottom**). The effect of moisture stress on root bottom angle was more pronounced at low K. At 60 and 20% FC, root bottom angle under 20 ppm K was significantly higher than other two K levels. At 60 ppm K, the high K concentration seems to override the effect of moisture stress as the root bottom angle at 20% FC was significantly lower compared to 20 and 40 ppm. At 60% FC, the root bottom angle difference between 40 ppm and 60 ppm was statistically not significant.

A substantially postive effect of increased K concentration under moisture stress was reflected in the overall growth of seedlings (**Figure 5**) and significantly, maximum dry weight of the most moisture-stressed seedlings was observed under 60 ppm K (**Figure 6**).

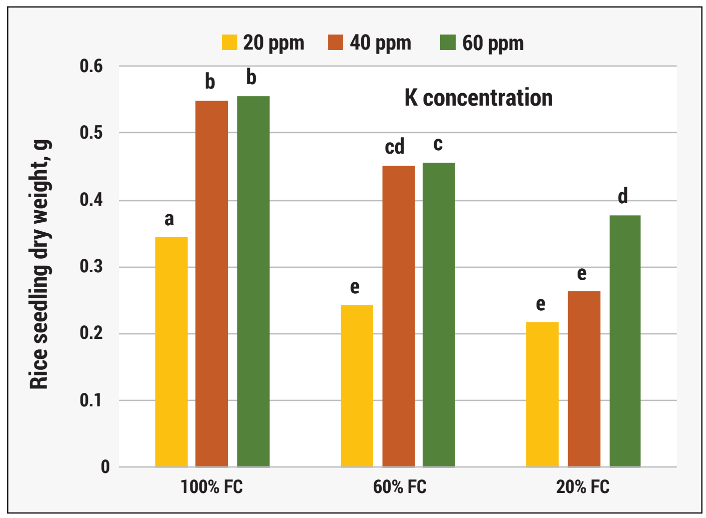

Figure 6. Effect of potassium and moisture availability on seedling total dry weight of rice (NAUR-1) at 21 DAE. Any two bars having a common letter does not differ from each other at *p*=0.05

Conclusion

Under conditions of moisture stress, a higher soil K concentration was found to be helpful in limiting any reduction in root area, promoting the maximum width of the root system, and increasing rooting depth. Decreasing root area is an adaptive feature of rice under moisture stress where the plant can save energy and carbon for increasing root depth to search for water. In our study, K was found to nullify this and rice plants were able to maintain root area along with root depth, which was helpful for exploration of soil profiles for efficient absorption of nutrients. At the higher application of K, rice seedling roots were able to maintain narrow root top and bottom angle under moisture stress which would facilitate exploration of more surface area and encourage increased absorption of other nutrients for maintaining seedling growth. **BC**

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