untreated generations, may increase the potential of adaptive evolution.

With this experimental demonstration of transgeneration memory of stress in plants[1], there is a need to search for a probable phenomenon underlying such heritable 'genomic shock'-related epigenetic messages. New traits arising in meristematic tissue in plants could be subject of selection, because a sort of germ-line is created late in the plant development[10]. There are reasons to believe that the unique occurrence of continual organogenesis in plants[11] owes to the inherent potential for epigenetic transfer of acquired changes across the generations. In all probability, the genesis of transgenerational capacity of stress-induced, increased genomic flexibility lay in the unique developmental property of plants rather than to any unusual genetic phenomenon. Unlike animals, there are no germ lines in plants, but the latter are uniquely armed with inbuilt mechanism of continual somatic organogenesis. Plants display profound genomic plasticity as a sequel to abiotic and biotic stresses, and readily generate 'genomic shock'-mediated epigenetic and genotypic variations in their somatic tissues. The potential variation-prone cells from within the somatic tissues carrying the so-called epigenetic factor, could be differentially selected during continual somatic organogenesis and transmitted to the progeny. In the vegetative progenies the transmission of variation-prone cell is facilitated by morphogenetic selection through somatic cell lineages entering into differentiating shoots, and in seed progenies through its selective passage to pre-meiotic L-II subepidermal layer. In both the situations the potential somatic selection of variation-prone cell for epigenetic/genomic variation is the determining factor for transgeneration of induced variation.

As such, it is the continual organogenesis and morphogenetic somatic sieve that offers plants the opportunity to unravel a range of variations that are generated *in situ* and accumulated during growth and development. Such accumulated build-up of potential hidden variation could be transgenerational even in seed progenies, and more so in vegetative progenies.

A practical corollary to the said findings[1] could be seen in asexual plants if the succession potential of stress-induced somatic changes were studied in segregating clonal progenies. Using a palaeopolyploid plant species, *Mentha arvensis* L. (family Lamiaceae), we have demonstrated that somatic mutations caused by genomic shock are selectively passed through the somatic sieve and potentially transmitted to subsequent vegetative generations through propagule-mediated clonal progenies[2]. The vegetative propagules (i.e. suckers) of this species when administered genomic stress, accumulate/acquire genomic changes, but the same is not revealed in a growing plant, albeit differentially transmitted to its fast proliferating suckers and unravelled in subsequent sucker-mediated clonal progenies. This clearly suggests transgeneration capacity of stress-induced genomic changes in vegetatively propagating plants. Such 'genomic shock'-induced changes could serve as a valuable resource for realizing variation in plants where sexual recombination is lacking or deficient.

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On the estimation of evapotranspiration, water-use efficiency and crop coefficient of lucerne (*Medicago sativa* L.) in central India

Lucerne or alfafa (*Medicago sativa* L.) is a major irrigated forage crop attaining high yields with high-forage quality potential. Its versatility in utilization, adaptations to a wide range of climate and soil conditions, soil improvement capability and symbiotic N_2 fixation make it preferable choice in intensive agricultural production system[1]. In India, it is grown successfully even in the low rainfall areas with assured irrigation[2]. The crop has relatively high-water demand and long production season and is exposed to periodic harvesting.

Efficient water management is key to success in augmenting crop production. Increasing the irrigation water-use efficiency necessitates improved irrigation scheduling techniques based on integrated effect of climate, soil and crop characteristics. Reliable estimate of evapotranspiration as a function of crop stage is important for determining crop water use and efficient irrigation management. Water stress in the plant can be quantified by actual evapotranspiration rate, as the level of evapotranspiration is related to the evaporative demand of the air[3]. Evapotranspiration loss and rate of evapotranspiration indicate the amount of water required at different growth periods for its satisfactory growth and optimum production. Crop coefficient represents crop specific water use and facilitates estimation of irrigation water requirements. Its significance for scheduling irrigation is shown earlier[4,5]. Experimentally determined crop coefficient values for North Indian[6–8] and Gujarat[9] region have been reported for different crops. However, the information on these aspects in relation to lucerne crop for the Indian region is

scanty. In the present study, an attempt has been made to determine the evapotranspiration, water-use efficiency and crop coefficient of lucerne in central India, which are important in assessing the actual water requirement of crop for irrigation scheduling and crop planning for different agroclimatic regions.

A field experiment was conducted during *rabi* season with annual lucerne (var. Anand-2) at the Central Research Farm, Indian Grassland and Fodder Research Institute, Jhansi for seven consecutive years from 1998–99 to 2004–05. However, the data for 2002–03 has been excluded, as the cutting period for this year did not match with the rest of the years. Jhansi (25°27′N, 78°35′E, 271 m asl) experiences an annual rainfall of 906.5 mm with 781 mm during *kharif* and 52 mm during *rabi* and annual potential evapotranspiration of 1512 mm. Soil of the experimental site was fine, loamy, mixed, hyperthermic typic Ustochrept. It was silty clay loam in texture, neutral in reaction (pH_2 7.35) and non saline (EC_2 0.09 dS/m) in salt content. The status of organic carbon (0.27%), available nitrogen (182 kg/ha) and available phosphorus (3.92 kg P/ha) in the soil was low, whereas available potassium content of the soil was in medium range (147.8 kg K/ha).

The crop was sown during the third week of November with a seed rate of 16 kg/ha and basal fertilizer dose of 20 kg N + 80 kg P_2O_5 + 40 kg K_2O/ha. Irrigation scheduling was done based on irrigation water : cumulative pan evaporation (IW/CPE) ratio of 1.0, and irrigation was kept as 60 mm per irrigation. Crop was grown following standard agronomic practices and four cuttings were taken at the interval of 74, 31, 31, 31 days respectively in all the years. For daily evapotranspiration measurement, two gravimetric lysimeters having dimension of 1.3 × 1.3 × 0.9 m and consisting of a sensitive type of weighing machine of 2000 kg capacity were used. These lysimeters were surrounded by five plots (15 × 5 m each) of crop with similar irrigation schedule to act as buffer. The sensitivity of the system was ±0.2 kg, which is equivalent to 0.12 mm of evapotranspiration or rainfall. The daily evapotranspiration was measured by recording successive weight loss and taking the rainfall into account. Crop received 8.2, 1.5, 19.3, 40.4, 41.0 and 51.8 mm of precipitation during the crop growth period of 1998–99, 1999–2000, 2000–01, 2001–02, 2003–04 and 2004–05 respectively. The potential evapotranspiration was calculated during crop period following the modified Penman method[5].

Results reveal that the dry matter yield increased (Table 1) with the advancement of cutting and a maximum of 3.26 t/ha was obtained in the fourth cut. However, the green biomass yield was maximum in second cut and thereafter showed a declining trend. This reduction in green biomass yield may be attributed to high temperature and low humidity prevailing during March–May, adversely affecting the regenerative capacity and growth of lucerne.

The total evapotranspiration losses varied from 101.9 to 224.8 mm in different cuttings (Table 1). Evapotranspiration rate of the crop showed an increasing pattern from first to fourth cutting. Its highest value (7.3 mm/day) corresponds to fourth cutting, which is in accordance with the environmental conditions that are likely to affect the evapotranspiration rate greatly. Therefore, evapotranspiration from a lucerne stand can vary considerably during the season, between growing cycles and years, because of variation in evaporative demand and canopy structure. Higher values of the evapotranspiration during third and fourth cutting reflect that these two cuttings could be considered as a critical phase for the water requirement in lucerne.

The total dry matter yields of respective years were related with the corresponding total crop evapotranspiration. A linear relationship was observed which is expressed as DMY = 0.0115 ET + 1.3956 (R^2 = 0.85), where DMY is the dry matter yield and ET, the total evapotranspiration. Evapotranspiration explained 85% variation in total dry matter production. In many experiments using lysimeters, it was shown that yield is often a linear function of evapotranspiration[10]. Further, a significant ($P < 0.01$) linear relationship between cut-wise dry matter production of lucerne as a function of evapotranspiration was established (Figure 1). The relationship explains 41.55% variation in the estimated value of cut-wise dry matter production of lucerne.

The estimated water-use efficiency for different cuttings ranged from 0.86 to 2.04 kg/cubic m with a maximum value in the second cut. During the first cut, lowest value (0.86 kg/cubic m) of water-use efficiency was noticed because the first cut is of longer duration due to lower air and soil temperature during this period

Table 1. Average yield, evapotranspiration and water-use efficiency of lucerne for six growing seasons

Cuttings	Green matter yield (t/ha)	Dry matter yield (t/ha)	Evapotranspiration (mm)	ET/day (mm)	Water-use efficiency (kg/cubic m)	Duration (days)
I	8.73	1.32	152.7	2.1	0.86	74
II	12.47	2.08	101.9	3.3	2.04	31
III	10.87	2.29	162.3	5.2	1.41	31
IV	12.13	3.26	224.8	7.3	1.45	31

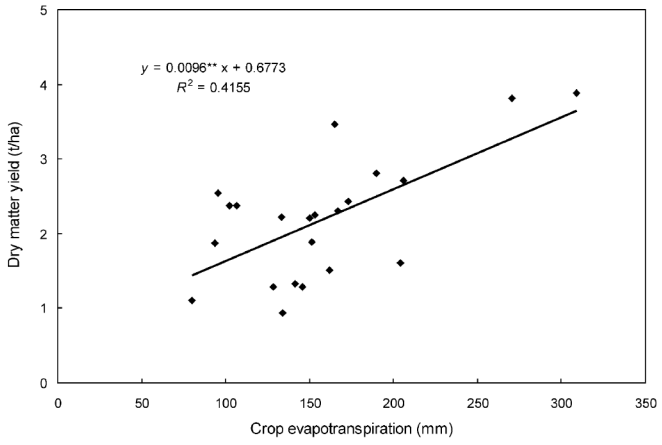

Figure 1. Cut-wise dry matter production of lucerne as a function of evapotranspiration.

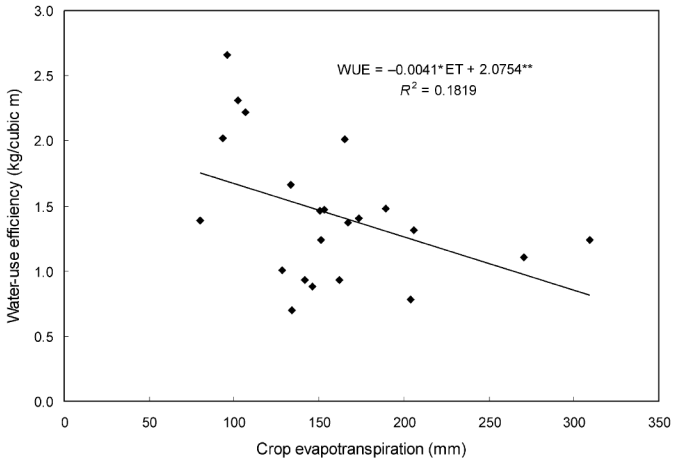

Figure 2. Cut-wise water-use efficiency of lucerne as a function of evapotranspiration.

Table 2. Crop coefficient of lucerne for different cuttings

Cuttings	Crop coefficient (*Kc*)		
	Germination	Establishment	Growth phase
I	0.57	1.1	1.40
	Regeneration		Growth phase
II	0.96		1.41
III	0.88		1.44
IV	0.85		1.46

which ultimately reduces the growth rate. Relatively lower water-use efficiency in third and fourth cutting is primiraly due to poor crop growth and higher evapotranspiration during this period. Several studies[11–14] have shown that the water-use efficiency of lucerne ranges from 0.5 to 3 kg/cubic m. However, the average water-use efficiency of irrigated lucerne in different environments[15] ranges from 1.4 to 2.3 kg/cubic m.

Evapotranspiration–water-use efficiency of lucerne varied according to climatic conditions, soil water regime, season, location, annual evapotranspitation and growth cycle. A negative linear relationship between annual water-use efficiency and water consumption in lucerne has been reported earlier[14,16]. Cut-wise water-use efficiency of lucerne as a function of evapotranspiration showed a significant ($P < 0.05$) negative linear relationship (Figure 2), which indicates that with increase in evapotranspiration, there would be decrease in water-use efficiency and vice versa.

Being a forage crop, lucerne is harvested several times during the growing season. In the present study, four cuts were taken and each cut has been subdivided into different phases. First cutting, which is of longer duration (74 days), is marked with three distinct phases, namely germination (15 days), establishment (21 days) and growth (38 days); whereas the rest of the cuttings were subdivided into regeneration phase (7 days) and growth phase (24 days). The crop coefficient (*Kc*) for different phases was determined by taking the ratio of actual to potential evapotranspirations. The estimated *Kc* values at different phases for different cuttings are presented in Table 2. It is observed that the *Kc* for lucerne is not a constant, since periodic harvests result in extended period of little ground cover. In the initial phase of crop growth, crop coefficient is less and with the progress of crop growth its value increased, being highest at the full growth stage indicating highest water use by the crop at that time. During first cutting, the *Kc* varied from a low value of 0.57 for germination phase to a peak value of 1.40 for growth phase having full ground cover. In the subsequent cuts (second to fourth), *Kc* varied from 0.85 to 0.96 during the regeneration phase and from 1.41 to 1.46 during growth phase. This variation in *Kc* accounts for the change in water consumption with development phases during each growth cycle. Such information on crop coefficient at different phenophases of crop is helpful in assessing the actual water requirement of the crop and hence in irrigation scheduling and crop planning for different agroclimatic regions.

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