SALT TOLERANT FORAGES FOR THE REUSE OF SALINE DRAINAGE WATER

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INTRODUCTION

Current practices for handling drainage water in the western San Joaquin Valley (WSJV) are not sustainable. The soil quality of 300,000 ha of land in the WSJV is adversely affected by the presence of shallow or perched water (0 to 1.5 m). Without a means of disposing of drainage water, increasing amounts of farmland in the WSJV will become salt impaired, and will be removed from production. Using drainage water to produce forages that are salt-tolerant would reduce the volume of drainage water and the amount of land needed for its disposal in evaporation ponds by up to an order of magnitude (Oster, 1997), thereby lowering the cost of disposal and limiting the exposure of wildlife to potentially toxic waters. High quality forages for dairy cattle, beef cattle, and sheep are in short supply in the Central Valley of California. Salt-tolerant forages may help provide improved forage supplies. Forage grasses like Bermuda grass (*Cynodon dactylon* (L.) Pers.) will use more water than most tree species in the same locations because of greater salt tolerance, and have an obvious use for livestock (Oster et al., 1997). However, agricultural drainage water in the WSJV often contains trace elements such as Se that can harm wildlife and livestock (Deverel and Millard, 1988; Fuji and Swain, 1995). These trace elements may adversely influence livestock performance and health and such possible effects must be monitored. If forage production using drainage waters can be coupled to livestock enterprises in sustainable ways, drainage water could become an asset rather than a problem.

There are a number of potentially useful forage grasses, but they vary in their salt tolerance. A partial list is presented in Table 1. The most tolerant species typically have poorer forage quality, including higher ash contents, unfavorable morphological characteristics like a tendency towards steminess (C4 grasses), slower disgestibility, and correlated reduced intake. A comparison between the cell wall characteristics of C3 and C4 grasses is provided in Table 2.

Many of the most salt tolerant forages are C4 types. Management is likely as important or even more important than the species chosen. Important forage quality characteristics are closely tied to the method of forage management used. For grasses, grazing often is the preferred management system, so the quality of grazing management will significantly influence the quality of the forages on offer to cattle or sheep. A well managed rotational grazing system will result in significantly improved forage quality and increased levels of forage and livestock production compared to indifferently managed pastures (Pearson and Ison, 1987).

In a drainage water reuse system, a balance must be reached among several factors that will vary from farm to farm. Most important are the quality of the land and drainage water available for the forage enterprise. Also, the objectives of the reuse system should be considered. If the reduction in drainage water volume is the primary objective, the system may be organized very differently from another in

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which the creation of a profitable grazing enterprise is the primary objective. The idea of using forage-livestock systems to manage drainage water is relatively new, or at least has been the subject of little quantitative research. The sustainabilty of drainage water reuse systems will be influenced by many complex, interacting factors. The results of continuous reuse of drainage water on salt-affected soils growing forages, and the effects on grazing animals cannot be easily predicted. Empirical research is required. A multi-disciplinary group of scientists and farm advisors has formed to establish a site for such research and to investigate the sustainablity of drainage water reuse. An 80 acre site has been provided by Westlake Farms near Stratford on land no longer suitable for annual crops. This site has been managed for the last year using drainage water to produce forages and has been grazed by beef cattle. Some initial results are reported here. A more detailed report describing the site, its assessment, and management is provided by Kaffka et al., (in press).

METHODS USED FOR BERMUDA GRASS ESTABLISHMENT AND SAMPLING

Bermuda grass was planted at the site in late summer 1999 (plots 1 to 4), and summer, 2000 (plots 5 to 8). Cultivar Giant was planted in plots 1 to 4 to allow both grazing and hay making, while cv. Common was planted in plots 5 to 8, for grazing purposes only. Systematic sampling of plots 1 to 4 began in late September of 2000, and of all eight plots in June 2001. Forage was sampled at locations selected initially for soil sampling and are based on natural variation is soil salinity and correlated soil chemical properties (fig.1). Plant material was collected from two 0.3 m by 1 m grids at each location, placed opposite each other approximately 1 m from the soil sample point. Soil sample points were located using a Trimble GPS system with an accuracy of less than 1 m. At each sampling, forage was collected at a new compass direction, to avoid re-sampling the same site. Sampling in this manner provides an estimate of standing biomass. While sampling, forage height before and after harvest was measured. Samples were dried, usually starting late the same day of collection, in a forced air dryer at 35^{o}C. After drying, forages were ground through a Wiley mill with a 1 mm screen and sub-sampled for quality analysis. Forages were analyzed for total N, crude protein, Ash, ADF and NDF, total P, K, S, Ca, Mg, Na, B, Zn, Mn, Fe, Cu, Mo, Se, and Cl. A small number of cattle (25) grazed the pastures during 2000 to assess livestock health effects, but there intake was very small relative to the biomass on offer.

RESULTS FROM BERMUDAGRASS ESTABLISHMENT AND YIELD TRIAL

Results are reported from sampling in fall 2000 and spring 2001 on plots 1 to 4 only. Bermuda grass is a halophytic, C4 species with a large degree of salt tolerance (Ayers and Westcott, 1976). Grass yields declined with increasing soil salinity in the first 30 cm of soil (Fig. 2). Above approximately 22 dS m^{-1}, little to no Bermuda grass was able to establish, or if it established, grew poorly. This response matched estimates of salinity tolerance reported by Ayers and Westcott and summarized in Table 1 (1976). Consequently, in locations with the largest amounts of soil B and Mo, there was no forage to collect, and none for cattle to graze. Standing biomass estimates for the 7 sample events carried out in 2001 are given in fig. 3. Units used in the figure can be converted to tons of hay. 500 g / 0.6 m^2 is approximately equal to 3.7 t dry matter per acre. Means, standard errors and other statistics for a sub sample of forages from the first four plots for two sample events in late 2000 are reported in Table 3. The forage quality values observed for Bermuda grass are similar to others commonly used for average estimates (NRC, 1988).

Only limited amounts of data have been reported on trace element uptake by Bermuda grass, so comparisons cannot be made with literature values. Large amounts of soil Mo and B are found at this site. But forage Mo levels were not particularly high, likely because Bermuda grass did not grow in locations with the largest amount of soil Mo. Reports of grass species Mo concentrations often cite 1 to 4 ppm as commonly observed values (Vlek and Lindsey, 1977; McBride et al., 2001; O'Connor et al., 2001). In particular, Mo may be toxic to cattle if consumed in large amounts, primarily by interfering with Cu metabolism (Suttle, 1991). Some samples are high in Mo, but on average, Mo concentrations reported are not excessive, especially in comparison to concentrations reported as typical for legumes like alfalfa and clover, which is usually 2 to 4 times as enriched as grass species growing under similar conditions (O'Connor et al., 2001). The ratio of forage Cu to forage Mo (3.3:1) in these samples is above the ratio often cited for concern (2:1), but Suttle (1991) has proposed that the the critical ratio declines as forage Mo increases. Cu levels of less than 5 ppm in the presence of soil Mo has been cited as of concern (Suttle, 1991). Average Cu levels are greater than 8 ppm in these samples (Table 3). Crude protein levels, ADF, K, P, Ca, and Mg levels all are close to standard values used in ratio formulation tables, in the absence of specific forage analyses (NRC, 1989). Ash contents are higher on average than those considered typical. At the highest ash levels found in these samples (>20%), some soil contamination likely occurred. Most of the recent concern for Mo toxicosis is associated with Mo uptake by forages from soils amended with sewage sludge (O'Connor et al., 2001; McBride et al., 2001). There are fewer studies discussing the uptake of Mo by forages from soils naturally abundant in Mo (Vlek and Lindsey, 1977), so the ability to make comparisons is limited. In many instances, concern over the effects of Mo in forages is influenced by the concentrations of other elements like S (Suttle, 1991). Few feeding studies and fewer actual grazing studies under such conditions have been reported, so further work on livestock performance and health on these pastures will be of interest. Livestock performance during the first year's grazing period appeared satisfactory with cattle gaining weight throughout the summer. Results will be reported elsewhere.

Forage livestock systems hold promise as a means of reducing the volume of saline drainage water that must be disposed in the San Joaquin Valley. The productive potential of such systems is largely unknown. The sustainability of drainage water reuse must be carefully evaluated.

REFERENCES

Ayers, R.S., and Westcot, D.W. (1976). Water Quality for Agriculture. Irrigation ad Drainage Paper 29. Food and Agriculture Organization. Rome, 1976. 97p.
Deverel, S.J., and Millard, S.P. (1988). Distribution and mobility of selenium and other trace elements in shallow ground water of the western San Joaquin Valley, California. Environ, Sci. & Tech. 22:687-702.
Fujii, R. and Swain, W.C. (1995). Areal distribution of selected trace elements, salinity, and major ions in shallow groundwater, Tulare Basin and southern San Joaquin Valley. USGS Water Resources Investigation Report 95-4048. Sacramento, California.
Kaffka, S.R., Corwin, D.E., Oster, J. D., Hopmans, J, Mori, Y., van Kessel, C., and van

Groenignen, J-W. (In press). Using forages and livestock to manage drainage water in the San Joaquin Valley: Initial site assessment. In: G. Sposito (ed.). Soil Quality and the Environment. Annual Report of Research Projects, 2000-2001. Kearney Foundation of Soil Science. University of California Division of Agriculture and Natural Resources. Oakland.

Jones, C.A. (1985). C_4 Grasses and Cereals. John Wiley and Sons, New York.. 419p.

McBride, M., Richards, B.K., Steenhuis, T., and Spiers, G. (2000). Molybdenum uptake by forage crops grown on sewage sludge applied soils in the field and greenhouse. J. Environ. Qual. 29:848-854.

NRC (1988). Nutrient Requirements of Dairy Cattle. 6th revised edition. National Academy press, Washington, D.C. 157 p.

O'Conner, G.A., Brobst, R.B., Chaney, R.L., Kincaid, R. L., McDowell, L.E., Pierzynski, G.M., Rubin, A., and Van Riper, G.G.. (2001). A modified risk assessment to establish standards for land application of biosolids. J. Environ. Qual. 30:1490-1507.

Oster, J. D., Kaffka, S.R., Shannon, M.C., and Grattan, S.R. (1999). Saline-sodic drainage water: a resource for forage production. In: Anon (ed). Proc. of the17th Int. Congress of ICID. September 1999, Granada, Spain.

Pearson, C.J. and Ison, R.L. (1987). Agronomy of Grassland Systems. Cambridge University Press. New York, 169 p.

Suttle, N.F. (1991). The interactions between copper, molybdenum, and sulphur in ruminant nutrition. Ann. Rev. Nutr. 4:121-140.

Vlek, P.L.G., and Lindsey, W.E. (1977). Molybdenum concentration in Colorado soils. Pp 619-650. In: Chappel, W.R., and Peterson, K.K.(eds.). Molybdenum in the Environment. Vol. 2. Marcel Dekker, New York.

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Table 1. Salt tolerances of selected forages, (EC_e , $dS\ m^{-1}$)

Species	Yield Loss (%)			
	0	*25*	*50*	*maximum ECe*
Tall wheatgrass (*Agropyron elongatum*)	7.5	9.9	19.4	31.5
Bermuda grass (*Cynadon dactylon*)	6.9	8.5	15	22
Perennial ryegrass (*Lolium perenne*)	5.6	6.9	12.2	19
Tall fescue (*Festuca eliator*)	3.9	5.8	13.3	23
Sudan (*Sorghum sudanese*)	2.8	5.1	14.4	26
Alfalfa (*Medicago sativa*)	2.0	3.2	8.0	14

Source: Ayers and Westcott (1976)

Table 2. Morphological characteristics of selected grasses

Photosynthetic pathway	**C3**	**C4**
Morphology	lacks bundle sheath anatomy, mesophyll cells predominate	bundle sheath anatomy collenchyma cells, resistant to degradation
Storage compounds	fructans, fructosans	starch
Cell wall characteristics	less crude fiber, less ligninified	more crude fiber, more liginified
Digestibility	faster, larger percentage	slower, smaller percentage
Examples	ryegrass, orchardgrass, fescue, wheatgrass	Bermuda grass, salt grass, paspalum, sudan

Source: Jones (1985)

Table 3. Selected forage quality and mineral contents from Bermuda grass harvests in fall, 2000.

Label	Mean	Minimum	Maximum	Range	SD	CV
CP (%)*	16.00	9.31	22.1	12.8	2.93	18.3
Ash (%)	13.1	8.27	23.0	14.75	2.98	22.8
ADF (%)	29.4	22.1	36.4	14.3	3.21	10.9
P (%)	0.22	0.15	0.34	0.19	0.039	17.6
K (%)	1.98	1.07	3.41	2.34	0.464	23.4
S (ppm)	7415	3780	9250	5470	1028	13.9
Ca (%)	0.488	0.35	0.77	0.42	0.102	20.9
Mg (%)	0.245	0.16	0.56	0.4	0.08	32.7
Na (%)	7855	3600	23920	20250	3395	43.4
B (ppm)	133.2	44	257	184	39.4	29.6
Cl (%)	0.878	0.36	3.31	2.95	0.462	52.6
Zn (ppm)	35.5	17	58	41	9.52	1.23
Mn (ppm)	80.8	46	132	86	18.5	22.9
Fe (ppm)	667.1	175	4714	4539	817	122.5
Cu (ppm)	8.06	4.2	13.7	9.5	1.74	21.6
Mo (ppm)	2.41	1.4	5.3	3.9	0.76	31.7
Se (ppb)	88.5	16	328	312	60	67.8

* % of dry matter. N = 60 samples. C:\Work\WORK\Reuse\Alfsymp 11-01.wpd

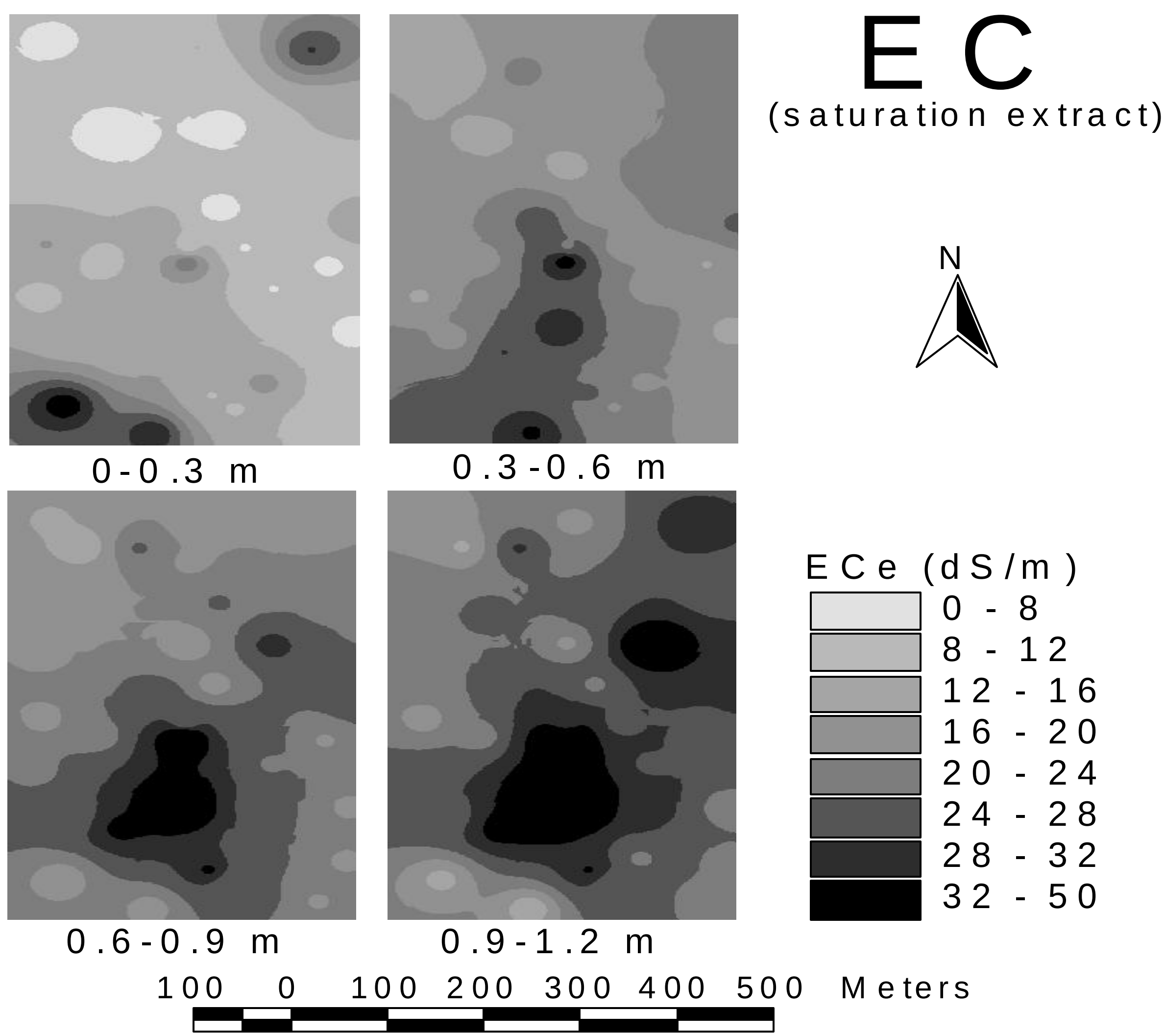

Fig. 1. Westklake Farms research site. Average EC_e (dS m^{-1}) to 4 feet deep. From Kaffka et al., (2000).

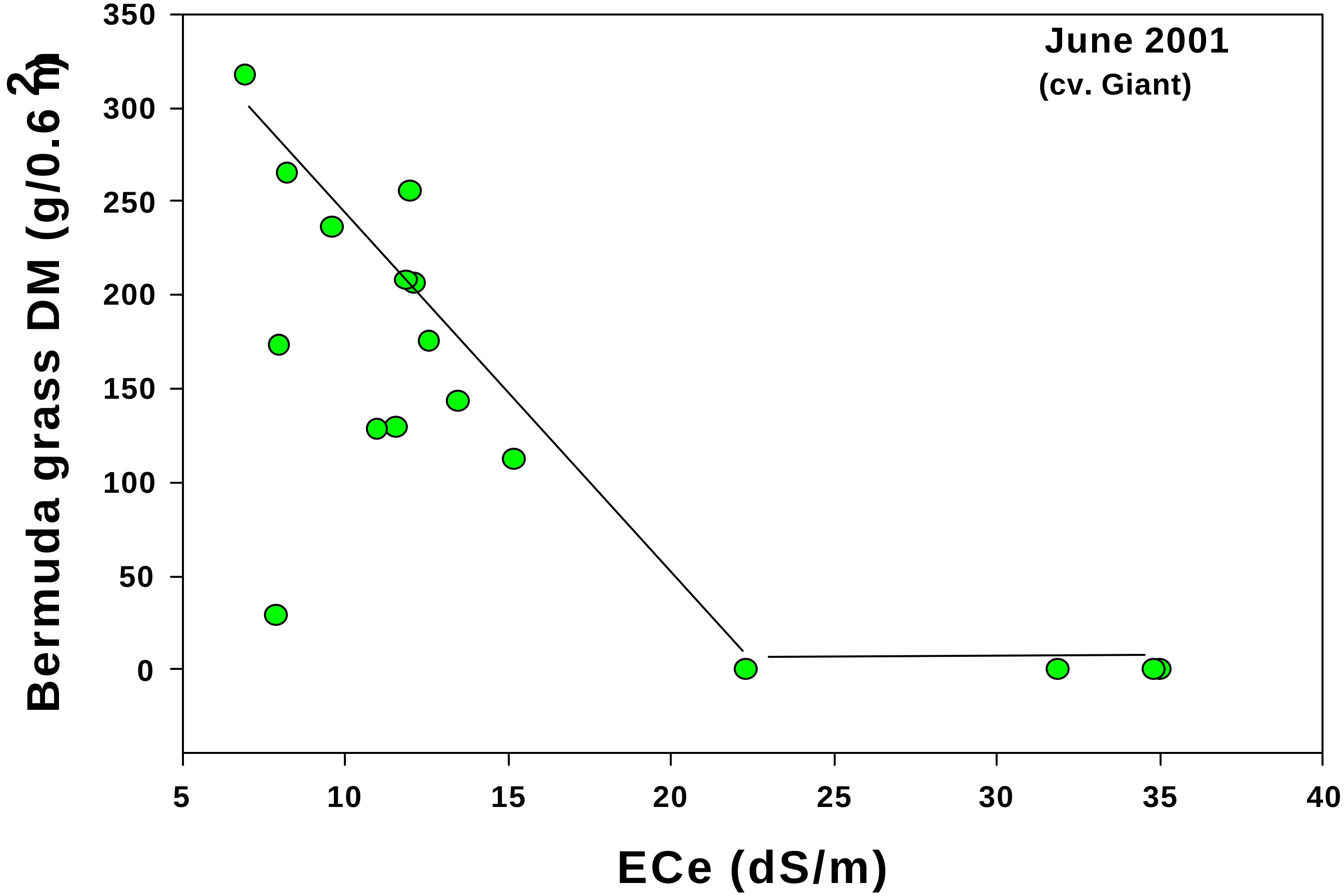

Fig. 2. Standing biomass (g DM 0.6 m^2) and EC_e (dS m^{-1}) in spring 2001. Westlake Farms research site.

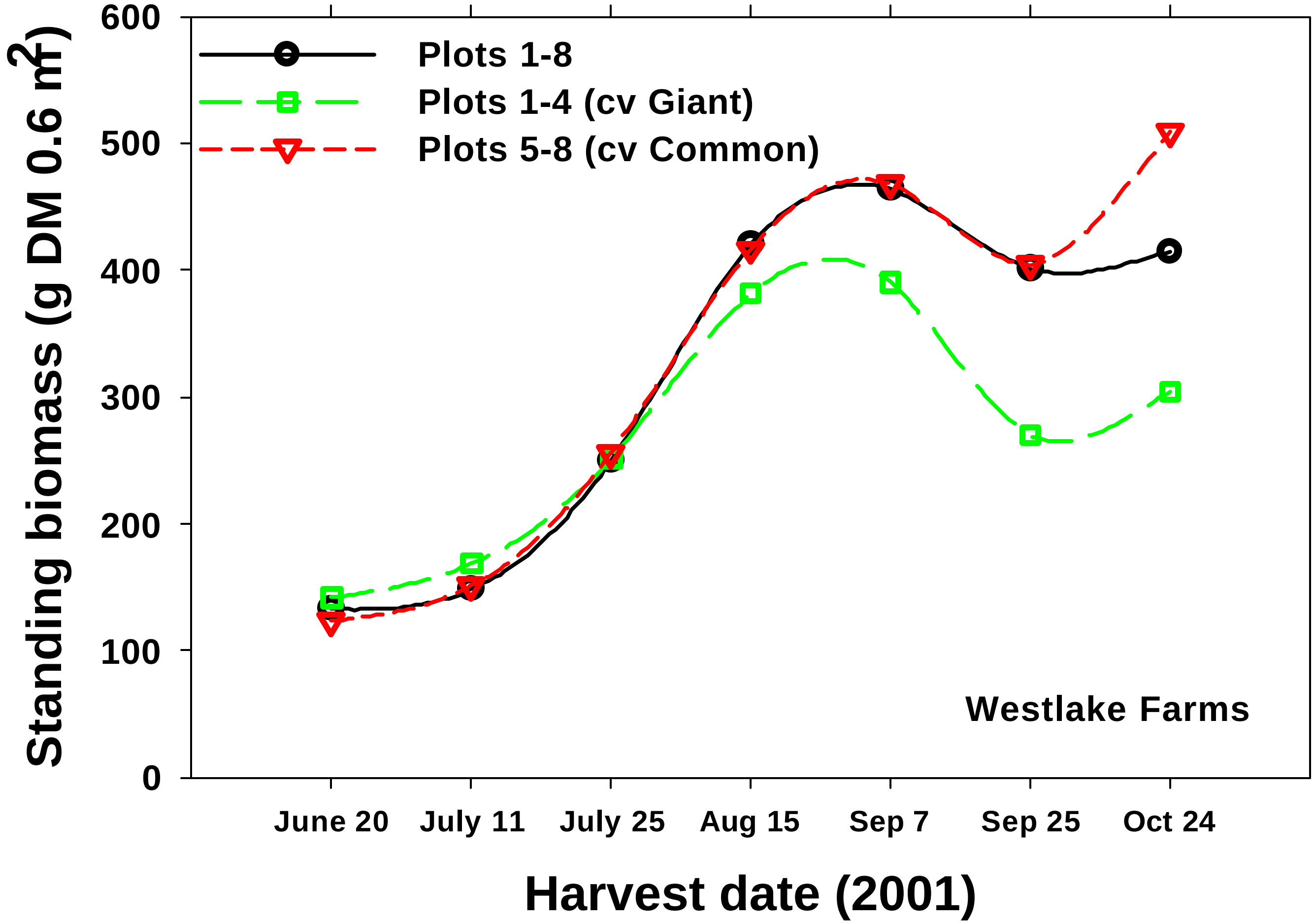

Fig. 3. Standing biomass (g DM 0.6 m^2) at seven sample dates in 2001. Westlake Farms research site.