Influence of planting depth and surface residue on osmotic potential in overwintering crown of wheat
by John Thomas DeNoma

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
Reduced tillage increases the amount of surface residue and alters the environment of the developing winter wheat plant. Osmotic potential of overwintering crown node tissue was measured during the fall and winter of 1983-84 and 1984-85 in wheats varying in winterhardiness.

The first objective examined the effect of planting depth and surface residue on the osmotic potential of crown node tissue in wheat. The second objective examined the relationship of osmotic potential in overwintering crown tissue and winterhardiness in cultivars of varying winterhardiness.

Increased planting depth and surface residue decreased crown osmotic potential. Winterhardy cultivars developed higher osmotic potential than less hardy cultivars in all treatments. Maximum osmotic potential was reached by January in both years. Crown node osmotic potential increased more rapidly in winterhardy cultivars with shallow planting and reduced surface residue than in less hardy cultivars.

Fall osmotic potential adjustment in winter wheat crowns could be used as a screening technique for winterhardiness. It also provides a means of evaluating the effect of surface residue on the acclimation of winter wheats under various tillage managements.

INFLUENCE OF PLANTING DEPTH AND SURFACE RESIDUE ON OSMOTIC POTENTIAL IN OVERWINTERING CROWNS OF WHEAT

by

John Thomas DeNoma II

A thesis submitted in partial fulfillment
of the requirements for the degree

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APPROVAL

of a thesis submitted by

John Thomas DeNoma II

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

4/13/90 — Date

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Approved for the College of Graduate Studies

June 5, 1990 — Date

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ABSTRACT

Reduced tillage increases the amount of surface residue and alters the environment of the developing winter wheat plant. Osmotic potential of overwintering crown node tissue was measured during the fall and winter of 1983-84 and 1984-85 in wheats varying in winterhardiness.

The first objective examined the effect of planting depth and surface residue on the osmotic potential of crown node tissue in wheat. The second objective examined the relationship of osmotic potential in overwintering crown tissue and winterhardiness in cultivars of varying winterhardiness.

Increased planting depth and surface residue decreased crown osmotic potential. Winterhardy cultivars developed higher osmotic potential than less hardy cultivars in all treatments. Maximum osmotic potential was reached by January in both years. Crown node osmotic potential increased more rapidly in winterhardy cultivars with shallow planting and reduced surface residue than in less hardy cultivars.

Fall osmotic potential adjustment in winter wheat crowns could be used as a screening technique for winterhardiness. It also provides a means of evaluating the effect of surface residue on the acclimation of winter wheats under various tillage managements.

INTRODUCTION

The winter wheat (Triticum aestivum L.) crown is the most important plant part influencing winter survival. During severe winters in northern latitudes the above ground portion of the wheat plant dies with little affect on spring regrowth if the crown is uninjured.

In northern latitudes the winter wheat crown must survive winters characterized by low temperatures, desiccating winds, and minimal snow cover. Winter wheat plants harden in the fall as a result of decreasing temperatures. Acclimation enables the plant to survive cold temperatures and desiccating winds. Winter injury occurs when soil temperatures drop below -20 C°, (Salmon, 1917, 1932; Worzella and Culter, 1941; Aase and Siddoway, 1979), or by desiccation at higher temperatures (Taylor and Olsen, 1985, 1986).

Osmotic potential may be related to winterhardiness in wheat (Johnson et al., 1984). Differences in osmotic potential of crown tissue have been reported in wheats varying in drought resistance and experience indicates a positive correlation between winterhardiness and drought resistance.

In recent years, changes in residue management reflect attempts to control soil erosion, improve water conservation, and reduce tillage costs. Increased surface residue alters the environment around the winter wheat plant and may alter crown node development, acclimation, and crown depth.

The first objective of this study was to examine the effect of planting depth and surface residue on the osmotic potential of crown node tissue in wheat. The second objective was to examine the osmotic potential in overwintering crown tissue of wheats varying in winter hardiness.

LITERATURE REVIEW

Osmotic Potential of Plant Tissue

Internal water status of plant tissues during stress is an important factor of plant survival. Measurement of a plant's water status was difficult until Spanner (1951) made the first breakthrough in the development of the thermocouple psychrometer, utilizing the Peltier effect to measure osmotic potential. Thermocouple psychrometer advancements during the early 1970's (Wiebe et al., 1971; Brown and Van Haveren, 1972) provided researchers a rapid and reliable means of measuring the water status of plants.

Osmotic potential of plant tissue controls numerous metabolic and biochemical processes, and the solute environment (Levitt, 1980a, 1980b; Green, 1983, Johnson et al., 1984). Wille (1985), Borowitzka (1981) and Fowler and Gusta (1977) found biochemical changes take place in wheat during the fall or with cooling temperatures. These include reduced water content and increased ion concentrations.

Osmotic potential is related to drought and desiccation resistance in wheat (Johnson et al., 1984). They showed that leaf tissue osmotic potential was greater in the drought resistant winter wheat cultivar, TAM W-101, than the less resistant cultivar, Sturdy. Keim and Kronstad (1979) found osmotic potential differences in response to drought stress among 10 winter wheat cultivars differing in drought resistance.

An inverse relationship between plant water content and winterhardiness in winter wheat and rye was reported by Nass (1983). Increased crown moisture content in three winter wheat and barley cultivars reduced plant survival at low temperatures (Metcalf et al., 1970). Decreases in crown moisture content in cold acclimated cereals were correlated to increased cold hardiness. Reduced cell water content was one of the first events to be observed during initiation of cold acclimation (Fowler and Carles, 1979).

Planting Depth

Taylor and McCall (1936) found deep planting increased the depth of the crown node while increased soil temperature decreased the crown depth in two wheat cultivars.

Ashraf and Taylor (1974) found subcrown internode length increased with planting depths up to 10 cm for dark grown seedlings. They also reported that winterhardy wheats tended to have more shallow crowns than less hardy wheats.

Cold hardiness of two hardy winter wheat cultivars, Kharkov 22 MC and Winalta, was found to decrease with increased planting depth (Freyman, 1978).

Surface Residue

Conservation or reduced tillage was developed to combat soil erosion, improve water conservation, and reduce tillage costs. Skidmore et al. (1979) estimated that 55 to 87% of the wind erosion could be controlled by leaving all crop residue on the surface. Lindstrom et al. (1979) calculated that the average soil loss in the corn belt for conventional tillage was 21.5 metric tons ha/year, where as the loss for no-till with 3,920 Kg/ha of surface residue was 6.5 metric tons ha/year.

Soil temperature is influenced by increased residue associated with reduced tillage. Baeumer and Bakermans (1973) found soils with mulch or increased residue at or near the surface warm slower at the surface during times of increasing spring temperatures. Soils remain cooler under heavy surface residue due to the increased amount of reflected heat energy. The opposite was true for times of decreasing temperatures. The soil surface cools faster with the lower portion of the soil profile remained warmer. This is characteristic of the fall in northern latitudes.

Aase and Siddoway (1979) found increased stubble height caused the mean soil temperatures at 3 cm crown depth to be warmer in the fall and increased the amount of snow trapped during the winter. Fenster et al. (1977) showed that surface residue rates from 1700 to 6700 Kg/ha significantly increased the moisture content of the soil over bare fallow, and reduced soil erosion. Gupta et. al. (1983) found surface residue or the lack of it, affected the soil thermal regimes altering root growth and nitrogen availability.

Soil temperature has been shown (Ferguson and Boatwright, 1968) to influence the depth of crown node formation in winter wheats. Warm soil temperatures resulted in shallower crowns. In addition these workers showed that the decreased light reaching the soil surface with high rates of residue influences crown node location; under low light conditions crown nodes of winter wheat form at shallower depths.

Cold Hardiness

Cold hardiness in wheat changes with temperature during the winter months (Worzella and Cutler, 1941; Levitt, 1980a). Maximum cold hardiness occurs during the 4th to 6th leaf stage of development in the fall (Andrews et al., 1960).

Acclimation in winter wheat occurs only after exposure to decreasing temperatures and the maximum develops under long photoperiods of early fall (Paulsen, 1968). Limin and Fowler (1985) found decreased root and leaf temperature increased cold hardiness in wheat. They also found that cold hardening was initiated by decreasing leaf temperature and progressed as root temperatures decreased. Reduced root temperatures had the highest correlation to reduced tissue water content.

MATERIALS AND METHODS

Cultivars

Four winter wheat cultivars varying in winterhardiness were grown in the field in 1984 and 1985 (Table 1). A fifth low hardy cultivar was added in 1985.

Table 1. Winter wheat cultivars studied in 1983-84 and 1984-85 and winterhardiness scores.

Cultivar	Winterhardiness score*	1983-84	1984-85
Froid	4.5	+	+
Yogo	4.3	+	+
Crest	2.5	+	+
Brawny	2.0	-	+
ORE FD#5	1.5	+	+

* Hardiness score, 5=hardy, 1=non hardy (Taylor and Olsen, 1985)

Experimental Design

The experimental design was a split-split plot with four replications, planted at two locations in two years. Planting depths (the first split) and two straw levels (the second split), are defined in Table 2.

Planting

Vitavax treated seed was seeded at 10 g/meter. Locations 1 and 2 were planted on September 24th and 25th, in 1983, and, locations 3 and 4 on September 26th and October 9th, respectively, in 1984. October 9th is considered as a late planting date at Bozeman, Montana. Location 2 in the first year was abandoned due to volunteer wheat.

In 1983-84, plots had three rows 3 m long spaced 30 cm apart. The center row was used for sampling. In 1984-85, plots consisted of six rows with samples obtained from the four center rows.

Table 2. Planting depths and straw levels for two locations in 1983-84 and 1984-85.

	Planting depth (cm)		Straw level (Kg/ha)	
Year	Shallow	Deep	No straw	Straw
1983-84	3.0	7.5	0	4500
1984-85	3.0	6.5	0	4500

Barley straw was applied at a rate of 4500 Kg/ha to the plots immediately after planting in 1983-84 and seven days after planting in 1984-85 (Table 2).

Locations 1, 3, and 4 were on Amsterdam silt loam soil classified in the mixed family of Typic Haploboralls.

Sampling Dates

Crown sampling dates are shown in Table 3 for the one location in 1983-84 and two locations in 1984-85.

Plant Sampling

A minimum of two plants from each plot were cut at the soil surface, extracted from the soil, washed and damp dried with a Kimwipe. A 0.7 cm segment extending upward from directly below the crown node was excised.

Segments from two plants were placed in the stainless steel psychrometer sample cup, capped with a rubber stopper, immediately frozen on dry ice and stored at -28.9 C (DeNoma, et al., 1986). Plant samples through November 17th, 1983 were removed from unfrozen soil with shovels. After December, this was accomplished by removing frozen blocks of soil containing intact plants.

Table 3. Crown sampling dates for osmotic potential measurement in 1983-84 and 1984-85 at three locations.*

1983-84	1984-85	
Location 1	Location 3	Location 4
NOV 4	NOV 6	NOV 9
NOV 17	NOV 16	NOV 25
NOV 30	NOV 29	DEC 15
DEC 7	DEC 7	JAN 2
DEC 20	DEC 18	JAN 20
JAN 2	DEC 27	FEB 17
JAN 20	JAN 7	
FEB 3	JAN 24	
	FEB 12	
	MAR 10	
	MAR 24	

1983-84 Location 2 abandoned due to volunteer wheat. *

The December 1984-85 plants were removed in frozen blocks of soil, the soil was placed in numbered one-quart Zip-Lock plastic freezer bags, and stored on dry ice in an insulated chest for transportation to the laboratory. After 30 minutes at room temperature, two plants were removed from the soil, washed, crown segments excised and deposited in the psychrometer sample cups. The cups were immediately capped with a rubber stopper, and frozen on dry ice for 10 minutes and then moved to -28.9 C° storage.

The sample cups containing the crown tissue were removed from -28.9 C° storage and equilibrated to room temperature of 22.0 to 23.5 C° for osmotic potential measurement.

Osmotic Potential Determination

Osmotic potential was determined with a Decagon SC-10 Thermocouple Psychrometer coupled with a Wescor HR-33T microvoltmeter used in the dew point and psychometric mode, and recorded by a MW-100 recording microvoltmeter (DeNoma et al., 1986). The Wescor HR-33T was used in the psychometric mode with a 30 second cooling time for all plant samples.

Statistical Procedures

An analysis of variance was conducted for each sampling date within a location. F tests for main effects and interactions for the split-split plot design were conducted treating all factors as fixed as outlined by Snedecor and Cochran (1980) and Little and Hills (1978). LSD (0,05) were computed within each sampling date. A pooled LSD value was computed to examine trends across sampling dates. This LSD value was computed using the error mean square and degrees of freedom pooled across sampling dates within a location.

MSUSTAT (Lund, 1985) was used in the computer analysis of the split-split plot design.

RESULTS AND DISCUSSION

Locations

Crown node osmotic potential generally differed significantly ($P < 0.05$) among sampling dates (Fig. 1); planting depth, straw levels, and cultivars for location 1 (Table 4), location 3 (Table 5) and location 4 (Table 6).

Osmotic potential decreased as fall progressed in 1983 and 1984, reaching its maximum development during the last of November through early January (Fig. 1). The general trend in osmotic potential lowering was similar over locations and years. However, in the late planted location 4, the soil froze to the depth of the crown node shortly after emergence. The osmotic potentials of the late planted location 4 were higher than the early planted location 3 and did not reach the minimum until early January. The decreased osmotic potential closely followed the increase in soluble sugars in response to decreasing fall temperatures found by Wille (1985).

After minimum osmotic potentials of -3.23, -2.99, and -2.78 Mpa were reached at locations 1, 3, and 4, respectively, a gradual increase occurred. Generally the increase continued until spring growth started. The increase in osmotic potential after mid-December resembled decreases in sugars found by Green (1983) and Wille (1985) in winter wheat crowns. Increased osmotic potential may also explain dehardening of wheat reported by Roberts and Grant (1968), Andrews et. al. (1974), and Gusta and Fowler (1976).

Planting Depth

Wheat planted 3 cm deep developed lower osmotic potential than planted at the deeper depths of 7.5 and 6.5 cm in 1983-84 and 1984-85, respectively (Fig. 2). Freyman (1978) found deep seeding reduced the winterhardiness level in the winterhardy wheats Karkov 22MC and Winalta.

Significant differences ($P < 0.01$) in osmotic potential between the two planting depths were found at all sampling dates and locations except on November 30th at location 1 (Table 4). Significant differences in osmotic potential at locations 3 and 4 are shown in Tables 5 and 6, respectively. The sampling procedure after November 30th was altered to decrease damage when plant were removed from frozen soil. The shallow planting had the lowest osmotic potential throughout the sampling period (Fig. 2).

In the first year the minimum crown osmotic potential peaked about a week earlier in the deep plantings than in the shallow plantings (Fig. 2). In the second year, the peaks occurred at about the same time in both shallow and deep plantings.

Plant development was more advanced in 1983-84 at location 1 with visibly larger primary roots and crown nodes than plants at location 3 in 1984-85. Although they were planted on similar dates, moderate fall weather in 1983 maximized plant growth and development before the soil froze. The cooler fall of 1984 decreased plant growth and development with the soil freezing two weeks earlier than in 1983. Plants were only at the one or two leaf stage when the soil froze at the late planted location 4. Plants in 1983 had well developed primary root systems with adventitious roots protruding from the developed primary root systems with adventitious roots protruding from the crown node. The primary root systems in 1984 were moderately developed at location 3 and poorly developed at location 4 by early November. No adventitious roots were evident at either location. The differences in root development among locations were likely due to temperature and planting date differences.

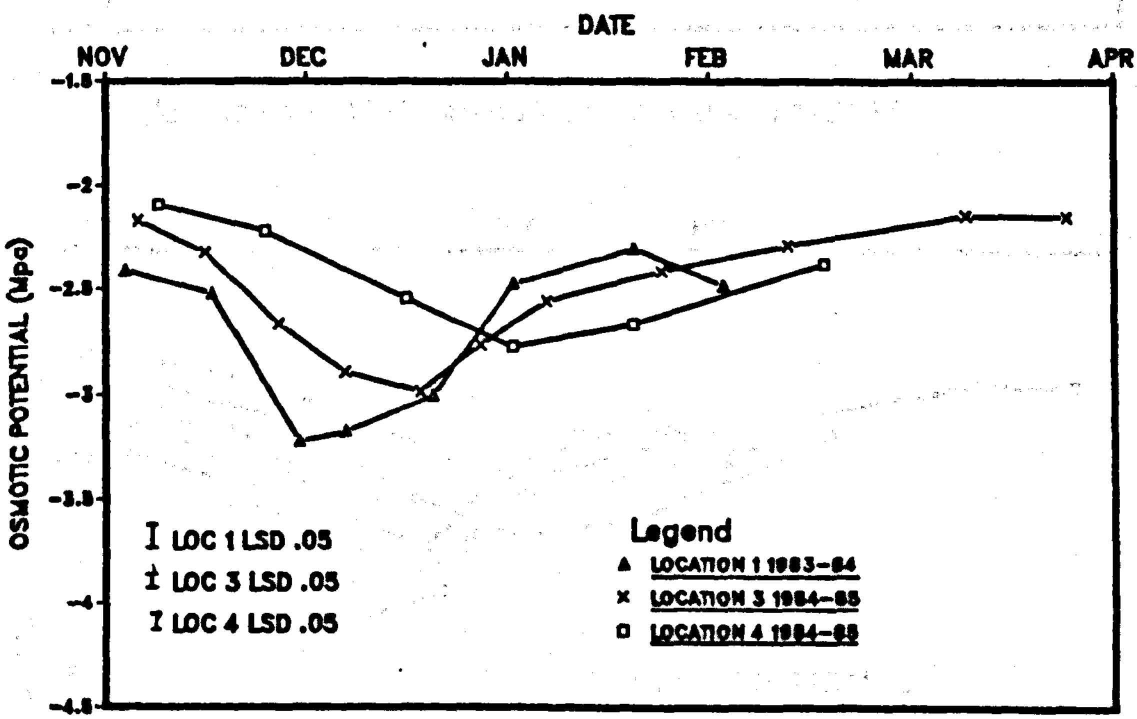

Figure 1. Mean osmotic potential of crown node tissue over all planting depths, straw levels, and cultivars for location 1 in 1983-84 and locations 3 and 4 in 1984-85.

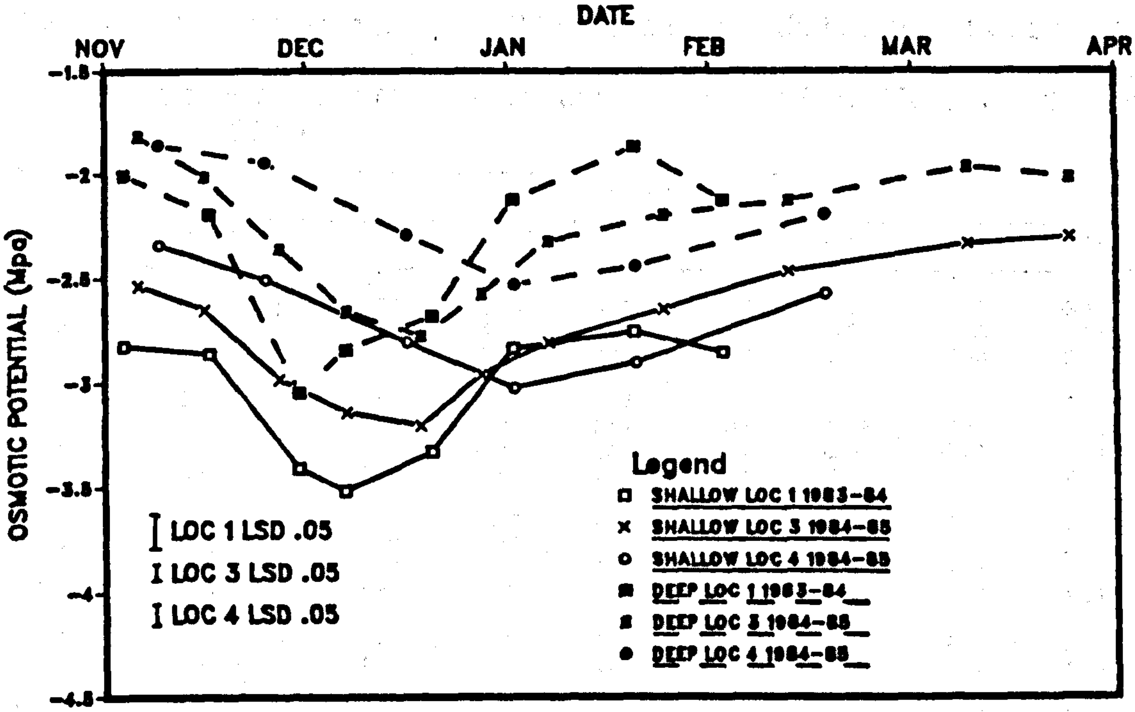

Figure 2. Effect of planting depth on osmotic potential of crown node tissue at location 1 in 1983-84 and location and 4 in 1984-85.

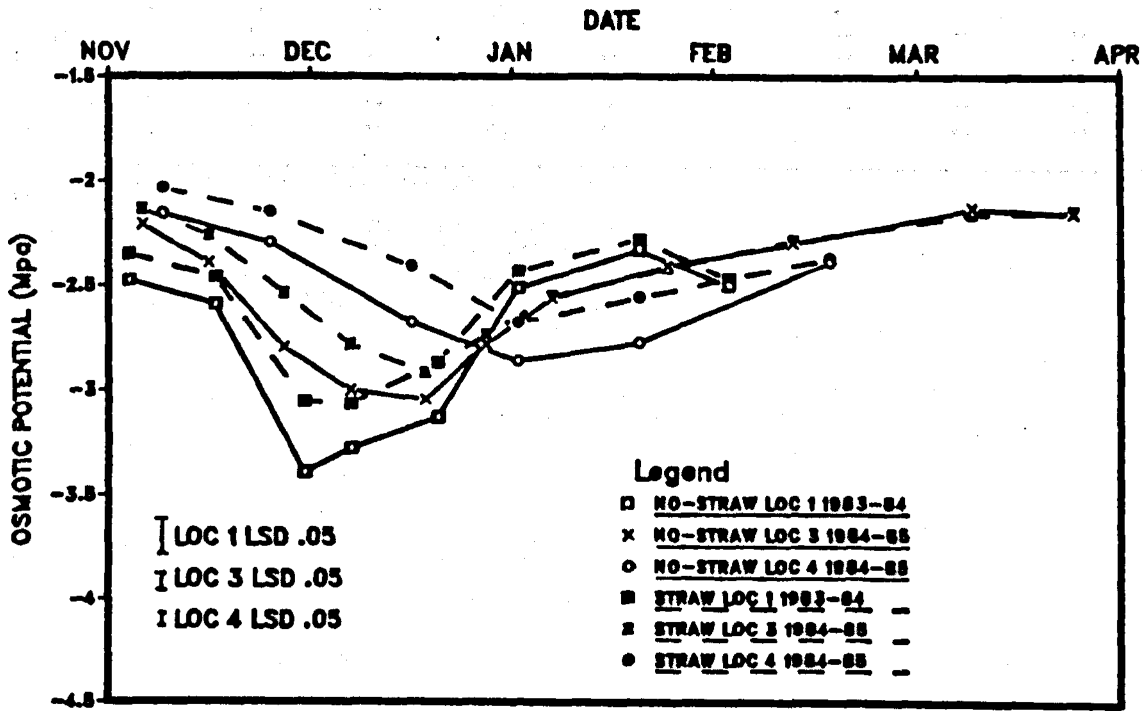

Figure 3. Effect of surface residue on osmotic potential of crown node tissue at location 1 in 1983-84 and location 4 in 1984-85.

Table 4. Mean osmotic potential (Mpa) of crown node tissue for two planting depths and two straw level combinations of four cultivars and significance of main effects and interactions from ANOVA at location 1 in 1983-84.

		Sampling dates							
Cultivar	Trt.	Nov 4	Nov 17	Nov 30	Dec 7	Dec 20	Jan 2	Jan 20	Feb 3
Froid	SNS	-3.56	-3.70	-4.31	-4.49	-4.24	-3.68	-3.46	-3.62
Yogo	SNS	-3.18	-3.23	-3.59	-4.08	-3.72	-3.17	-3.06	-3.18
Crest	SNS	-3.40	-3.43	-4.06	-4.15	-4.01	-3.31	-3.30	-3.36
ORE FD#5	SNS	-2.18	-2.12	-2.92	-2.73	-2.80	-2.03	-2.15	-2.01
Froid	SS	-2.51	-2.56	-2.99	-3.35	-3.06	-2.47	-2.48	-2.50
Yogo	SS	-3.17	-3.23	-3.46	-3.77	-3.46	-3.19	-3.14	-3.12
Crest	SS	-2.48	-2.70	-3.12	-3.28	-3.11	-2.84	-2.37	-2.94
ORE FD#5	SS	-2.08	-1.90	-2.84	-2.29	-2.25	-1.97	-2.06	-2.08
Froid	DNS	-1.99	-2.20	-3.07	-2.88	-2.68	-2.13	-1.81	-2.06
Yogo	DNS	-1.86	-2.00	-2.88	-2.77	-2.54	-1.94	-1.60	-2.00
Crest	DNS	-2.25	-2.57	-3.55	-3.06	-3.08	-2.50	-2.01	-2.47
ORE FD#5	DNS	-1.38	-1.49	-2.77	-2.01	-2.03	-1.40	-1.30	-1.35
Froid	DS	-2.86	-3.03	-3.07	-3.82	-3.45	-2.95	-2.79	-2.92
Yogo	DS	-1.57	-1.84	-3.03	-2.65	-2.39	-1.75	-1.46	-1.75
Crest	DS	-2.51	-2.64	-2.97	-3.19	-3.01	-2.53	-2.43	-2.60
ORE FD#5	DS	-1.64	-1.80	-3.02	-2.24	-2.27	-1.80	-1.54	-1.87
LSD .05		.06	.08	.32	.08	.16	.06	.05	.06
Depth (Dep.)		*	**	NS	**	**	*	**	**
Straw (Str.)		**	NS	**	**	NS	**	NS	
Straw X Depth		**	**	NS	**	**	**	**	**
Varieties (Var.)		**	**	*	**	**	**	**	**
Dep. X Var.		**	**	NS	**	**	**	**	**
Str. X Var.		**	**	*	*	NS	**	**	**
Str. X Dep. X Var.		**	**	NS	**	**	**	**	**

*, ** Significant at .05 and .01 levels of probability, respectively.
NS Not significant.
SNS Shallow planting depth (3.0 cm), no-straw (0 Kg/ha)
SS Shallow planting depth (3.0 cm), Straw (4500 Kg/ha)
DNS Deep planting depth (7.5 cm), no-straw (0 Kg/ha)
DS Deep planting depth (7.5 cm), straw (4500 Kg/ha)

Table 5. Mean osmotic potential (Mpa) of crown node tissue for two planting depths, two straw level combinations of five cultivars and significance of main effects and interactions from ANOVA at location 3 in 1984-85.

		Sampling Dates										
Cultivar	Trt.	Nov 6	Nov 16	Nov 27	Dec 7	Dec 18	Dec 27	Jan 7	Jan 24	Feb 12	Mar 10	Mar 24
Froid	SNS	-3.23	-3.52	-4.14	-4.35	-4.29	-3.74	-3.51	-3.42	-3.27	-3.16	-3.15
Yogo	SNS	-3.01	-3.09	-3.41	-3.75	-3.81	-3.63	-3.28	-2.99	-2.90	-2.63	-2.70
Crest	SNS	-3.13	-3.25	-3.52	-3.60	-3.53	-3.13	-3.17	-3.13	-2.83	-2.66	-2.59
ORE FD#5	SNS	-2.01	-2.05	-2.48	-2.57	-2.66	-2.41	-2.31	-2.14	-1.93	-1.73	-1.59
Brawny	SNS	-2.10	-2.36	-2.56	-2.58	-2.76	-2.67	-2.50	-2.20	-1.91	-1.91	-1.86
Froid	SS	-2.47	-2.51	-2.62	-2.94	-3.11	-3.03	-2.95	-2.82	-2.58	-2.53	-2.58
Yogo	SS	-2.95	-2.95	-3.27	-3.51	-3.61	-3.44	-3.23	-3.17	-2.92	-2.62	-2.70
Crest	SS	-2.26	-2.37	-2.74	-3.00	-2.93	-2.86	-2.68	-2.51	-2.43	-2.44	-2.11
ORE FD#5	SS	-1.95	-2.26	-2.48	-2.64	-2.61	-2.24	-2.17	-1.99	-1.87	-1.75	-1.71
Brawny	SS	-2.24	-2.13	-2.58	-2.47	-2.72	-2.44	-2.24	-2.08	-1.97	-1.89	-2.00
Froid	DNS	-1.63	-1.92	-2.68	-3.01	-2.73	-2.35	-1.95	-1.96	-2.00	-1.69	-1.83
Yogo	DNS	-1.72	-1.82	-2.49	-2.81	-2.86	-2.54	-2.13	-2.00	-2.20	-2.01	-2.17
Crest	DNS	-2.20	-2.62	-2.50	-2.99	-2.98	-2.77	-2.54	-2.54	-2.43	-2.28	-2.37
ORE FD#5	DNS	-1.46	-1.53	-1.93	-2.05	-2.35	-2.13	-2.01	-1.59	-1.50	-1.45	-1.46
Brawny	DNS	-1.63	-1.82	-2.29	-2.40	-2.57	-2.53	-2.29	-2.17	-2.05	-1.83	-1.89
Froid	DS	-2.73	-2.83	-2.96	-3.25	-3.57	-3.33	-3.02	-2.98	-2.81	-2.36	-2.44
Yogo	DS	-1.42	-1.64	-2.34	-2.56	-2.75	-2.41	-2.27	-2.11	-2.12	-2.01	-2.21
Crest	DS	-2.22	-2.44	-2.54	-2.79	-2.95	-3.00	-2.48	-2.35	-2.15	-2.18	-2.12
ORE FD#5	DS	-1.51	-1.67	-1.87	-2.19	-2.45	-2.28	-2.14	-2.00	-1.85	-1.83	-1.72
Brawny	DS	-1.63	-1.84	-2.01	-2.53	-2.53	-2.41	-2.38	-2.25	-2.15	-2.00	-1.91
LSD .05		.06	.10	.06	.06	.06	.06	.07	.06	.09	.07	.06
Depth (Dep.)		**	**	**	**	**	**	**	**	**	**	**
Straw (Str.)		**	**	**	**	**	**	NS	NS	NS	NS	NS
Straw X Depth		**	**	**	**	**	**	**	**	**	**	**
Varieties (Var.)		**	**	**	**	**	**	**	**	**	**	**
Dep. X Var.		**	**	**	**	**	**	**	**	**	**	**
Str. X Var.		**	**	**	**	**	*	**	**	**	**	*
Str. X Dep. X Var.		**	**	**	**	**	**	**	**	**	**	**

*,** Significant at .05 and .01 levels of probability, respectively.
NS Not significant.
SNS Shallow planting depth (3.0 cm), no-straw (0 Kg/ha)
SS Shallow planting depth (3.0 cm), Straw (4500 Kg/ha)
DNS Deep planting depth (6.5 cm), no-straw (0 Kg/ha)
DS Deep planting depth (6.5 cm), straw (4500 Kg/ha)

Table 6. Mean osmotic potential (Mpa) of crown node tissue for two planting depths, two straw level combinations of five cultivars and significance of main effects and interactions from ANOVA at location 4 in 1984-85.

		Sampling Dates					
Cultivar	Trt.	Nov 9	Nov 25	Dec 15	Jan 2	Jan 20	Feb 17
Froid	SNS	-3.01	-3.26	-3.85	-4.09	-3.95	-3.21
Yogo	SNS	-2.70	-2.97	-3.20	-3.40	-3.52	-3.24
Crest	SNS	-3.19	-3.24	-3.43	-3.41	-3.30	-2.84
ORE FD#5	SNS	-1.70	-1.96	-2.08	-2.51	-2.40	-1.98
Brawny	SNS	-2.02	-2.12	-2.48	-2.45	-2.33	-2.20
Froid	SS	-2.31	-2.55	-2.73	-2.89	-2.91	-2.81
Yogo	SS	-2.69	-2.72	-2.97	-3.45	-3.21	-3.13
Crest	SS	-2.14	-2.37	-2.62	-2.88	-2.77	-2.45
ORE FD#5	SS	-1.68	-1.82	-2.15	-2.70	-2.63	-1.85
Brawny	SS	-1.97	-2.08	-2.51	-2.43	-2.04	-2.00
Froid	DNS	-1.49	-1.90	-2.62	-3.01	-2.85	-2.12
Yogo	DNS	-1.61	-1.77	-2.74	-2.75	-2.70	-2.03
Crest	DNS	-2.36	-2.36	-2.51	-2.66	-2.69	-2.51
ORE FD#5	DNS	-1.56	-1.73	-1.88	-1.93	-1.73	-1.51
Brawny	DNS	-1.49	-1.68	-2.02	-2.51	-2.34	-2.28
Froid	DS	-2.53	-2.67	-2.88	-3.03	-3.00	-2.97
Yogo	DS	-1.50	-1.61	-2.12	-2.45	-2.60	-2.35
Crest	DS	-2.43	-2.38	-2.47	-2.70	-2.52	-2.30
ORE FD#5	DS	-1.48	-1.58	-1.78	-1.93	-1.87	-1.94
Brawny	DS	-1.62	-1.76	-1.90	-2.37	-2.13	-1.92
LSD .05		.13	.06	.07	.07	.06	.07
Depth (Dep.)		**	**	**	**	**	**
Straw (Str.)		**	**	**	**	**	NS
Straw X Depth		**	**	**	**	**	**
Varieties (Var.)		**	**	**	**	**	*
Dep. X Var.		**	**	*	**	**	**
Str. X Var.		**	**	**	**	**	**
Str. X Dep. X Var.		**	**	**	**	**	**

*,** Significant at .05 and .01 levels of probability, respectively.
NS Not significant.
SNS Shallow planting depth (3.0 cm), no-straw (0 Kg/ha)
SS Shallow planting depth (3.0 cm), Straw (4500 Kg/ha)
DNS Deep planting depth (6.5 cm), no-straw (0 Kg/ha)
DS Deep planting depth (6.5 cm), straw (4500 Kg/ha)

Surface Residue

Crown osmotic potential of wheat under bare fallow was significantly lower ($P < 0.05$) than with surface residue during acclimation at all locations (Fig. 3). Following minimum crown osmotic potential, differences in crown osmotic potential between the bare and straw residue decreased. Crown osmotic potentials were similar after December at locations 1 and 3 (Fig. 3). Mean crown osmotic potential under bare fallow was significantly lower ($P < 0.01$) than surface residue at the late planted location 4 until February 17th (Fig. 3). Differences in osmotic potential between surface residue levels at location 4 were greater and endured longer than earlier planted location 3 the same year.

The minimum osmotic potential for the straw covered plots and bare plots was reached at the same time in both years at each location (Fig. 3). In the first year, the minimum osmotic potential was reached at location 1 in early December. In the second year, the minimum was reached by late December and early January for location 3 and location 4, respectively.

In both deep and shallow plantings, surface residue decreased the plants ability to develop osmotic potential as low as the shallow planted no-straw treatment (Tables 4, 5 and 6). The residue level was roughly equivalent to heavy residue found under reduced or no-till farming practices. The effect of the straw was less by the end of December. Generally, there were significant differences ($P < 0.05$) between surface residue levels during acclimation. After the minimum osmotic potential was developed the difference was reduced and generally not significant.

The straw level by planting depth interaction was significant ($P < 0.01$) at locations 1 (Table 4), 3 (Table 5) and 4 (Table 6) with exception of the November 30th sampling date at location 1. The lowest crown node osmotic potential was produced under shallow planting in both years. Straw and deep planting reduced the plants ability to develop minimum osmotic potential at all locations (Tables 4, 5 and 6).

Cultivars

Contrasts of the hardy cultivars, Froid and Yogo, verses the less hardy cultivars, Crest and ORE FD#5 at location 1 in 1983-84 (Table 7), and Crest, Brawny, and ORE FD#5 in 1984-85 were used for the four treatments at locations 3 (Figs. 4, 5, 6 and 7) and 4 (Table 8). Differences between the hardy and less hardy cultivars at Location 3 for all planting depth and surface residue combinations was typical of the three locations (Figs. 4, 5, 6 and 7). Osmotic potential of the hardy cultivars under shallow planting, with or without straw, was significantly ($P < 0.05$) lower than the less hardy cultivars at all locations (Table 4, 5 and 6). Similar differences ($P < 0.05$) were found under the deep planting with straw treatment at all locations with the exception of the November 30th sampling date at location 1. The deep planting no-straw treatment had the smallest osmotic potential differences at the sampling dates between the hardy and less hardy groups at all locations (Tables 7, 8, and 15). The crown osmotic potential of the hardy cultivars was significantly lower ($P < 0.05$) at maximum osmotic potential than the less hardy cultivars. Generally, Crest had the lowest crown osmotic potential under deep planting bare fallow at all locations (Tables 4, 5 and 6).

Cultivar crown node osmotic potential differed significantly (P < 0.01) for all sampling dates at all locations (Tables 4, 5, and 6). Crown node osmotic potentials of the more hardy cultivars, Froid, Yogo, and the medium hardy cultivar Crest were lower than the less hardy cultivars, ORE FD#5 and Brawny (Tables 4, 5 and 6). The position and ranking of the less hardy cultivars compared to the hardy cultivars was not significantly affected by planting depth or residue level.

Roberts and Grant (1968) found plant development influenced cold hardiness in a wide range of winter wheat cultivars varying in winterhardiness with a more advanced level of development associated with increased hardiness.

The osmotic potential of the winterhardy cultivars Froid and Yogo reacted differently to straw and planting depth in the first year at location 1 (Table 4) and at the two locations the second year (Tables 5 and 6). Froid and Yogo both developed the highest osmotic potential under the shallow planting no-straw treatments (Tables 4 and 6; Figs. 8 and 9). This treatment is equivalent to normal planting depth in bare fallow in the northern great plains, and allows maximum crown temperature fluctuation. Froid's lower osmotic potential than Yogo may account for Froid having slightly higher winterhardiness score (Taylor and Olsen, 1985).

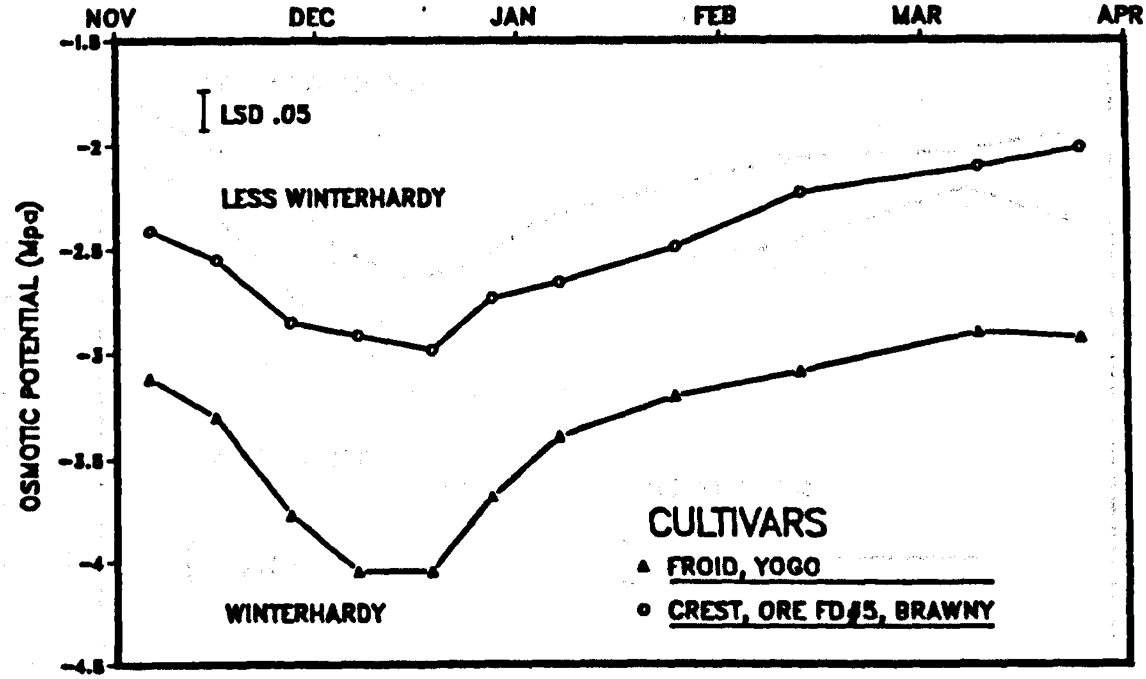

Figure 4. Mean osmotic potential of crown node tissue of the winter-hardy cultivars of Froid and Yogo Verses the less winterhardy cultivars of Crest, ORE FD#5, and Brawny under shallow planting no-straw treatment at location 3 during 1983-84.

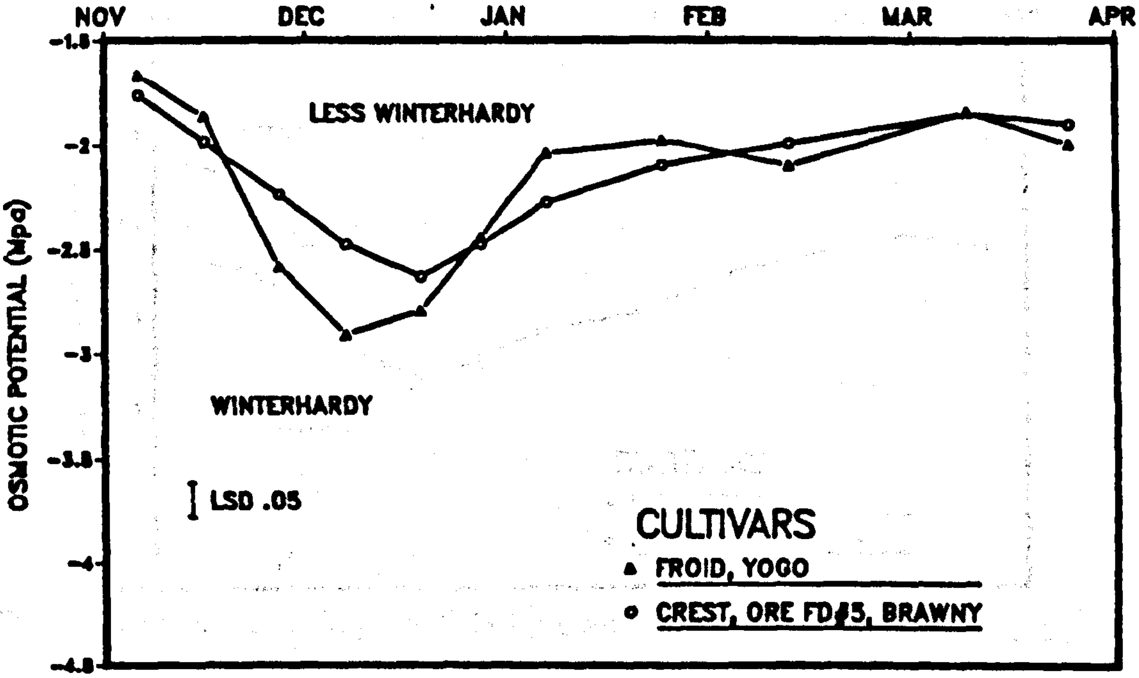

Figure 5. Mean osmotic potential of crown node tissue of the winterhardy cultivars of Froid and Yogo verses the less-winterhardy cultivars of crest, ORE FD#5, and Brawny under deep planting, no-straw treatment at location 3 during 1983- 84.

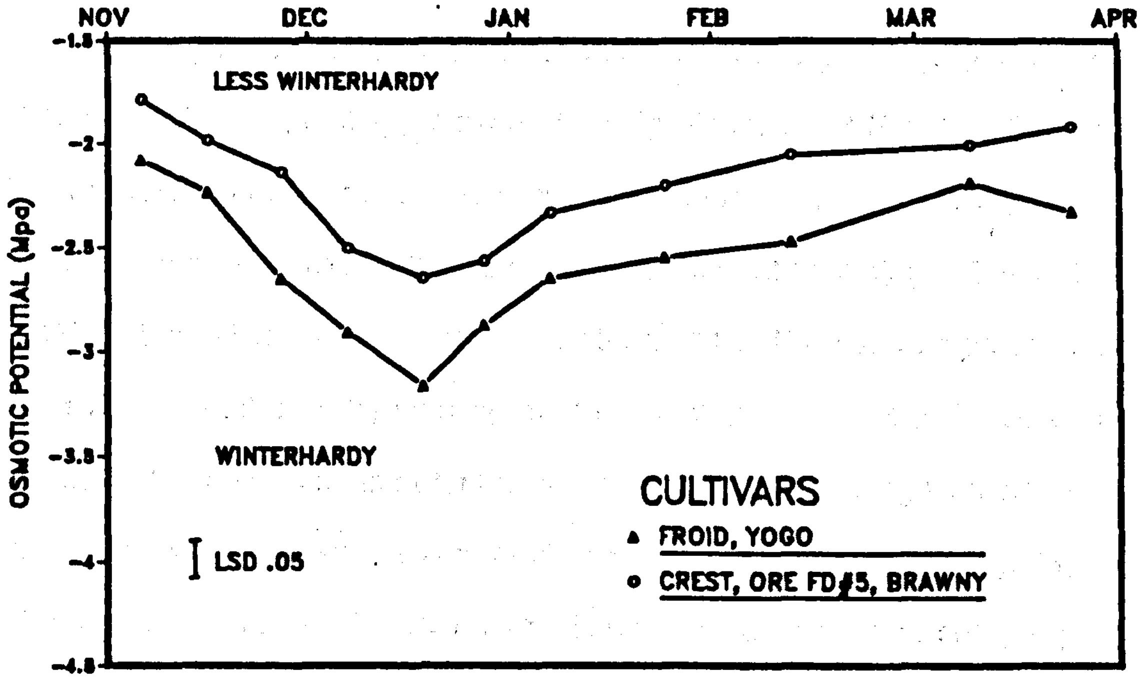

Figure 6. Mean osmotic potential of crown node tissue of the winter hardy cultivars of Froid and Yogo verses the less-winterhardy cultivars of Crest, ORE FD#5, and Brawny under shallow planting, straw treatment at location 3 during 1983-84.

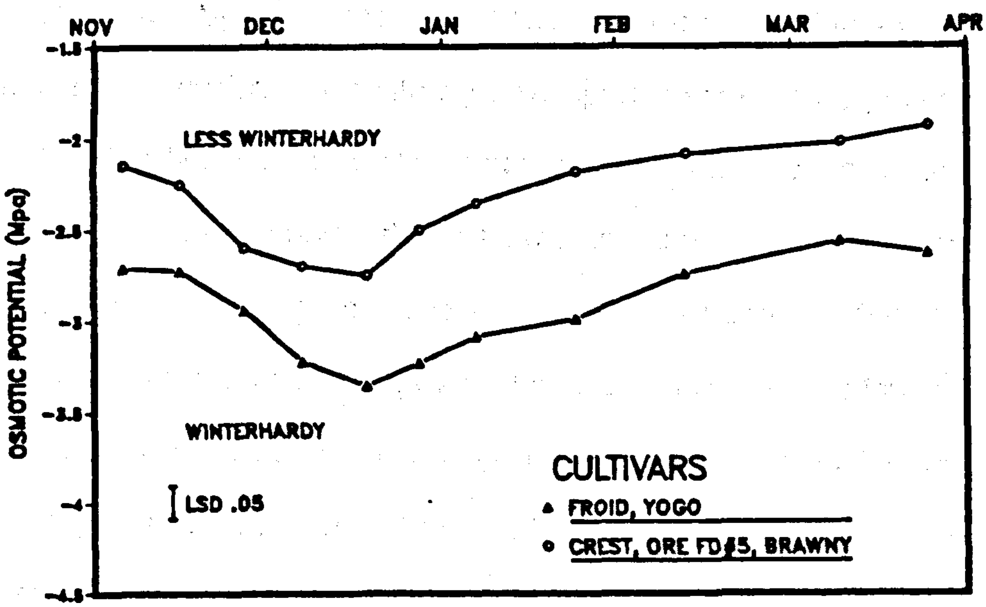

Figure 7. Mean osmotic potential of crown node tissue of the winterhardy cultivars of Froid and Yogo verses the less winterhardy cultivars of Crest, ORE FD#5, and Brawny under deep planting straw treatment at location 3 during 1983-84.

Although the crown node osmotic potential of Yogo was significantly higher with deeper planting, straw had no significant affect (Fig. 9). Generally Froid developed greater crown osmotic potential in the deep planting straw treatment and the shallow planted no-straw treatment than Yogo, Crest, Brawny or ORE FD#5 (Tables 4, 5, and 6; Fig. 10 and 11). The osmotic potential of Froid was less affected by planting depth than Yogo. Yogo developed and maintained higher osmotic potential under the shallow planting with straw treatment than the other cultivars at all locations (Tables 4 and 6; Fig. 11). Winter wheat cultivars differed in osmotic potential according to cropping residue management systems.

There were significant differences among cultivars and generally significant cultivar by treatment interactions at all locations (Table 4, 5, and 6). The winterhardy cultivars consistently developed lower osmotic potential than did the less hardy cultivars. Osmotic potential of Yogo was significantly ($P < 0.05$) greater than Froid under the shallow planting no-straw treatment and significantly greater under the shallow planting straw treatment (Fig. 10 and 11).

The crown node osmotic potential of Crest, a medium to lower winterhardy cultivar, was similar to Yogo under the shallow planting no straw treatment (Fig. 6) and similar to Froid under the shallow planting with straw treatment (Fig. 7). Crest developed significantly lower crown osmotic potential than Froid or Yogo under the deep planting no straw treatment at locations 3 and 4 (Tables 5 and 6) and the first two and last sampling dates at location 1