Reduction of Fusarium Root Rot and Sclerotinia Wilt in Beans with Irrigation, Tillage, and Bean Genotype

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ABSTRACT

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The influence of sprinkler irrigation regimes on yield of dry beans was evaluated as affected by deep tillage to reduce soil compaction, soil infestation with *Fusarium solani* f. sp. *phaseoli*, and cultivar resistance to the pathogen. The effect of these practices on Sclerotinia wilt was evaluated. There was little yield response to deep tillage in the absence of the *Fusarium* pathogen. When it was present, yield increases attributed to deep tillage were greatest in the most *Fusarium*-susceptible cultivar (Red Mexican UI-36) and lowest in the most *Fusarium*-resistant cultivar (Roza Pink). Yield increases resulting from increased irrigation were greater on *Fusarium*-infested than on noninfested soil. Injury from Sclerotinia wilt increased with increasing irrigation in *Fusarium*-free fields but was negligible in *Fusarium*-infested fields.

The two most serious diseases of irrigated dry beans (*Phaseolus vulgaris* L.) in the Northwest are root rot, caused by *Fusarium solani* (Mart.) Appel & Wr. f. sp. *phaseoli* (Burk.) Snyd. & Hans., and Sclerotinia wilt (white mold), caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. Injury from root rot can be reduced by maintaining an adequate supply of water to the root system (3). Sclerotinia wilt, which is encouraged by a dense, humid canopy (2), can be controlled by maintaining a dry foliar environment. Growers often are faced with the dilemma of whether to irrigate frequently to offset root rot injury or to withhold water to reduce the threat of Sclerotinia wilt. This report covers a 3-yr field study of the integrated use of sprinkler irrigation, deep tillage to reduce soil compaction, and bean genotype to counteract Fusarium root rot and the effect of these practices on incidence of Sclerotinia wilt.

MATERIALS AND METHODS

The studies were conducted near Prosser, WA, from 1979 to 1981 on a Warden loam (coarse-silty, mixed, mesic Xerollic Camborthids). Duplicate studies were conducted on *Fusarium*-free soil and on soil heavily infested with *F. solani* f. sp. *phaseoli* from many years of bean monoculture. Irrigation regimes were obtained with either of two techniques: the line-source system of Hanks et al (4) or a solid-set sprinkler system. Dry bean cultivars were used that varied in resistance to the *Fusarium* pathogen: Red Mexican UI-36 with low resistance and Roza Pink with high resistance. The deep-tillage treatments consisted of subsoiling to a depth of 0.5 m with shanks 0.56 m apart or not subsoiling.

Experimental design. The plot arrangement varied with the irrigation system, but a split-split plot design was used with both systems.

Line-source system. This technique (4) allows one to compare a wide range of irrigation rates within a relatively small area. A line-source study occupied an area 28 × 125 m. The variables were deep tillage as whole plots, bean cultivars as subplots, and irrigation rates as sub-subplots. Individual plots were one row wide and 6 m long. Treatments were replicated four times.

Solid-set system. Irrigation treatments were established as whole plots, tillage as subplots, and cultivars as sub-subplots. Each cultivar plot was four rows wide and 9 m long. In 1980, four replicates of four irrigation treatments were used, and only *Fusarium*-infested soil was involved. In 1981, six replicates of two irrigation treatments were used with duplicate sets on *Fusarium*-infested and noninfested soil.

Cultural operations. Seedbeds were prepared by the usual procedures for the area, which include preplant irrigation, fertilizer broadcast (nitrogen at 112 kg/ha; phosphorus, potassium, and zinc at rates determined by soil test), plowing or disking followed by cultipacking, incorporating herbicides, and planting in mid-May in rows 56 cm apart at a seeding rate of 112 kg/ha.

Just before herbicide incorporation, appropriate plots were subsoiled. At planting, any compaction caused by herbicide incorporation was removed on these plots by pulling a shank 0.25 m deep in front of and offset 5 cm from the planter. After planting, solid-set sprinklers were installed at the corners of 9-m-square plots. Irrigation was uniform until irrigation treatments were initiated.

Irrigation treatments. *Line-source system.* Fields were uniformly irrigated with solid-set sprinklers until bean foliage provided approximately full ground cover (mid- to late July) and the soil was near the upper limit of available water. The line sources then were installed lengthwise through the fields, which were irrigated daily until near harvesttime at rates equivalent to the estimated evapotranspiration (Et) at the line source. An evaporation pan with an appropriate crop factor was used to estimate Et (5). Applications decreased linearly with distance from the line source, becoming zero at 14 m away.

Each row was treated as an irrigation rate. Even though these rates were arranged systematically along the imposed irrigation gradient rather than randomly, the probability of a soil productivity gradient coinciding with the irrigation gradient on each side of the line source was low. Accordingly, the data were analyzed as if the irrigation treatments had been randomized.

Solid-set system. Treatments varied between 1980 and 1981. In 1980, the area was preirrigated and planted as described previously. Before full cover, one-half of the plots were irrigated on 27 June and 3 and 8 July, receiving about 15 mm of water per irrigation. All plots were irrigated on 12 July, about the time of full cover. Then each group of plots was split into two treatments: 1) irrigation to replace estimated Et every 3–5 days, or when about 25–40 mm of water had been removed, and 2) elimination of every other irrigation, resulting in a total postcover application about one-half that of treatment 1. Thus, there were four irrigation combinations for precover and postcover periods (Table 1).

In 1980, the pre-full-cover irrigations had a relatively small effect on bean yields. Therefore, in 1981, only the post-full-cover treatments were varied in the same manner as in 1980; before full cover, all plots were uniformly irrigated as

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needed.

***Sclerotinia* evaluation.** Infestation by *S. sclerotiorum* was evaluated in all of the studies. In the line-source areas, we weighed the sclerotia found in the threshed seed of each plot. Some sclerotia were lost with the straw during the threshing. In the solid-set studies, we counted the mature plants showing symptoms of Sclerotinia wilt. Either of these methods gives an index of the degree of Sclerotinia infestation. We did not attempt to relate the two sets of data.

Table 1. Four irrigation combinations used during precover and postcover periods in 1980

Treatment	From planting to full cover	After full cover
Dry-dry	Not irrigated	Every other irrigation omitted
Dry-wet	Not irrigated	Irrigated every 3–5 days
Wet-dry	Irrigated	Every other irrigation omitted
Wet-wet	Irrigated	Irrigated every 3–5 days

Harvest. *Line-source system.* Each plot consisted of one row 6 m long. Plants were hand-pulled and piled at one end of the plot on about 1 September. When dry, they were threshed and the seeds were cleaned and weighed.

Solid-set system. Each plot consisted of four rows 9 m long. About 1 September, bean plants were cut, with the four rows combined in one windrow. When dry, they were threshed and the seeds were cleaned and weighed.

RESULTS AND DISCUSSION

Line-source plots (daily irrigation). The results from these studies are dominated by the presence or absence of Fusarium root rot. *Fusarium*-free fields had little yield increase resulting from deep tillage in either year with any cultivar, and all cultivars yielded well (Fig. 1A,B). Where root rot occurred, cultivar yield response to deep tillage, as well as to the inherent levels of *Fusarium* resistance, varied from year to year. During the seedling growth period, 1979 was warmer than 1980; maximum air temperatures averaged 26.4 and 22.1 C, respectively, during the 6 wk after planting. Corresponding pan evaporations were 38.8 and 28.8 cm. In 1979, with the resulting warm soil and minimal predisposing stress (3), *Fusarium* injury was not severe (Fig. 1A), and even the root rot-sensitive UI-36 yielded well. The effect of deep tillage was slight, similar to that on *Fusarium*-free soil, and only UI-36 showed a positive response. In contrast, the cool weather in 1980 increased *Fusarium* injury (Fig. 1B), and the degree of injury was related to the inherent resistance to root rot in the cultivars. Roza Pink, the most resistant, was least affected, whereas UI-36, the most sensitive, had severely reduced yields compared with those obtained on root rot-free soil. All cultivars responded positively to deep tillage on the *Fusarium*-infested soil, with yield increases of 20% for Roza Pink, 48% for Aurora, and 80% for UI-36.

Response to irrigation and injury from Sclerotinia wilt were greatly influenced by root rot infestation. This is shown in Figure 2A for 1979, the year with only small root rot-induced yield reductions. In the *Fusarium*-free soil, Sclerotinia wilt was severe near the line source. Typical symptoms of Sclerotinia wilt diminished with distance from the line and were not observed further than about 6 m from the line. Sclerotia were found in the threshed seed from nearly all rows at all irrigation rates but were most numerous where symptoms of Sclerotinia wilt were apparent. Incidence of sclerotia was no less in cultivar Aurora, which is considered more tolerant to Sclerotinia wilt (1) than the other cultivars. The decline in yields closer to the line source is attributed to *Sclerotinia* injury resulting from increased irrigation water.

On the *Fusarium*-infested soil, sclerotia also were found in most seed samples, even though symptoms of Sclerotinia wilt were not observed during the season. These sclerotia were much smaller and fewer in number than those from *Fusarium*-free soil. Bean yields generally increased with increased irrigation, and there were no yield decreases attributable to *Sclerotinia* at the higher irrigation rates. Plant size and vigor correlated with numbers of sclerotia found in the seed. Pinto UI-114 and Roza Pink produced more sclerotia than the shorter-vined UI-36. This high incidence of *Sclerotinia* sclerotia without obvious wilt symptoms or effect on seed yield has not, to our knowledge, been reported before. Such incidence of sclerotia, evidently from incipient infections, could be very important in epidemiology of the disease.

In 1980, as in 1979, bean yields from the *Fusarium*-free soil decreased at the

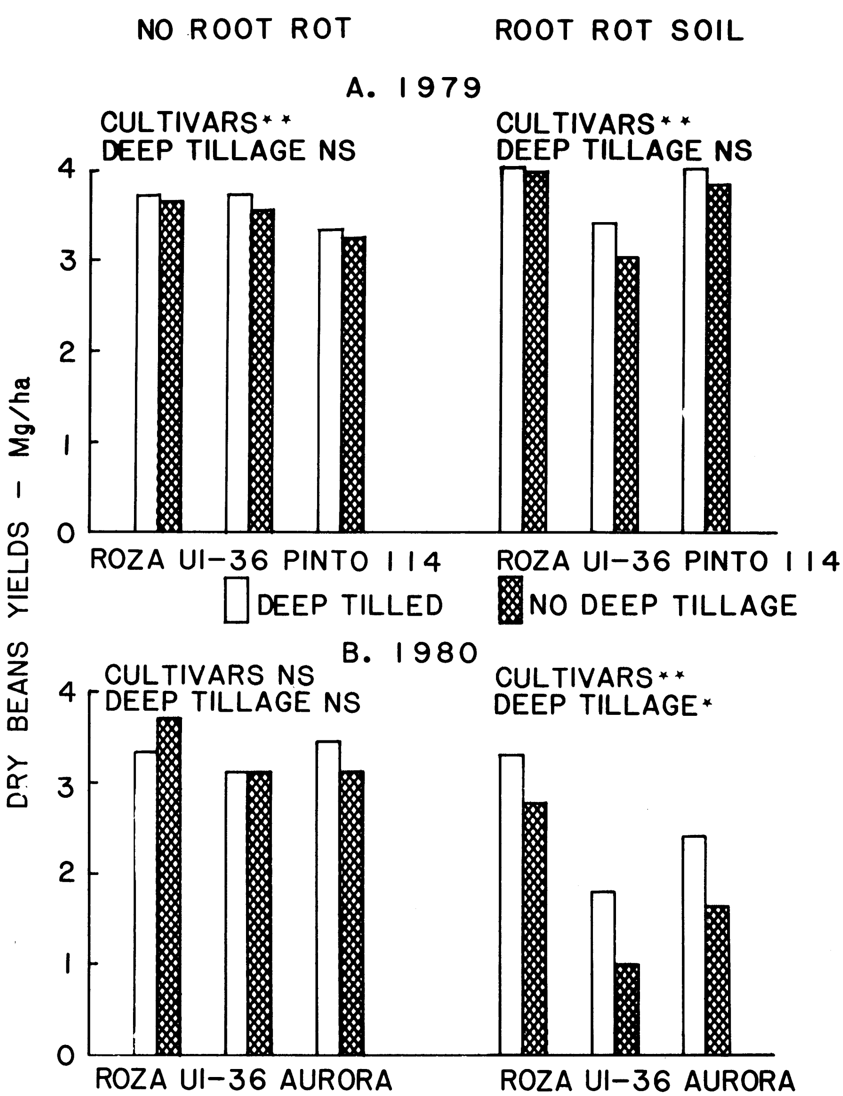

Fig. 1. Dry bean seed yields as affected by year, deep tillage, and cultivar resistance to Fusarium root rot during **(A)** 1979 and **(B)** 1980. Data are averages of all irrigations. * = Significantly different at $P = 0.05$ and ** = significantly different at $P = 0.01$. NS = not significantly different at $P = 0.05$.

higher irrigation rates, and this is attributed to *Sclerotinia* injury (Fig. 2B). A gradient in Sclerotinia wilt incidence and severity associated with the rate of irrigation was obvious in the field without Fusarium root rot but not in the field with root rot. Yields from the *Fusarium*-infested field were lower than from the *Fusarium*-free field at all irrigation rates.

Solid-set systems (intermittent irrigation). *Irrigation regime.* Irrigation before full canopy cover (a variable only in 1980) had relatively little effect on bean yield (Fig. 3). Early irrigations combined with deep tillage tended to increase yields, but this interaction was not statistically significant. The effect of irrigation regime on yield of dry beans was dominated by the presence or absence of Fusarium root rot (Fig. 4) and the level of cultivar resistance to the disease (Figs. 3 and 4). In the *Fusarium*-infested soil, bean yields were increased by full replacement of Et compared with only one-half replacement (alternate irrigations omitted). In the field without *Fusarium* infestation, the irrigation regime had a minor effect on yield (Fig. 4). There was a significant interaction ($P = 0.05$) between irrigation and cultivar in that yields of UI-36 decreased slightly with increased irrigation while those of Roza Pink did not. An explanation for this effect could be that UI-36 had more plants infected with *Sclerotinia* than did Roza Pink (Fig. 4), especially on the deep-tilled plots.

Deep-tillage effects. Yields were consistently increased by deep tillage compared with normal tillage when soil was infested with *F. solani* f. sp. *phaseoli* (Figs. 3 and 4). Averaged over both cultivars and irrigation regimes, deep tillage increased yields about 35 and 43% in *Fusarium*-infested soil in 1980 and 1981, respectively, but only 10% in the noninfested soil in 1981. Both cultivars responded positively to deep tillage, and irrigation regime had little effect on this response. The relative effect of deep tillage was greater for root rot-susceptible UI-36 than for resistant Roza Pink on the *Fusarium*-infested soil. Yield increases attributed to subsoiling were 58 and 25% in 1980 and 67 and 35% in 1981 for UI-36 and Roza Pink, respectively.

Cultivar effects. Root rot-resistant Roza Pink consistently outyielded root rot-sensitive UI-36, and the degree of increase was magnified when the soil was infested with *Fusarium* (Figs. 3 and 4). In 1981, on noninfested soil, Roza Pink yielded about 20% more than UI-36. When the soil was infested, the yield increase was 84% in 1980 and 160% in 1981. Root rot-sensitive UI-36 yielded only about one-third as much on *Fusarium*-infested soil in 1981 as it did on noninfested soil. Resistant Roza Pink yield was reduced only about 12% by root rot in 1981.

Sclerotinia infection. Incidence of *Sclerotinia* infection differed with

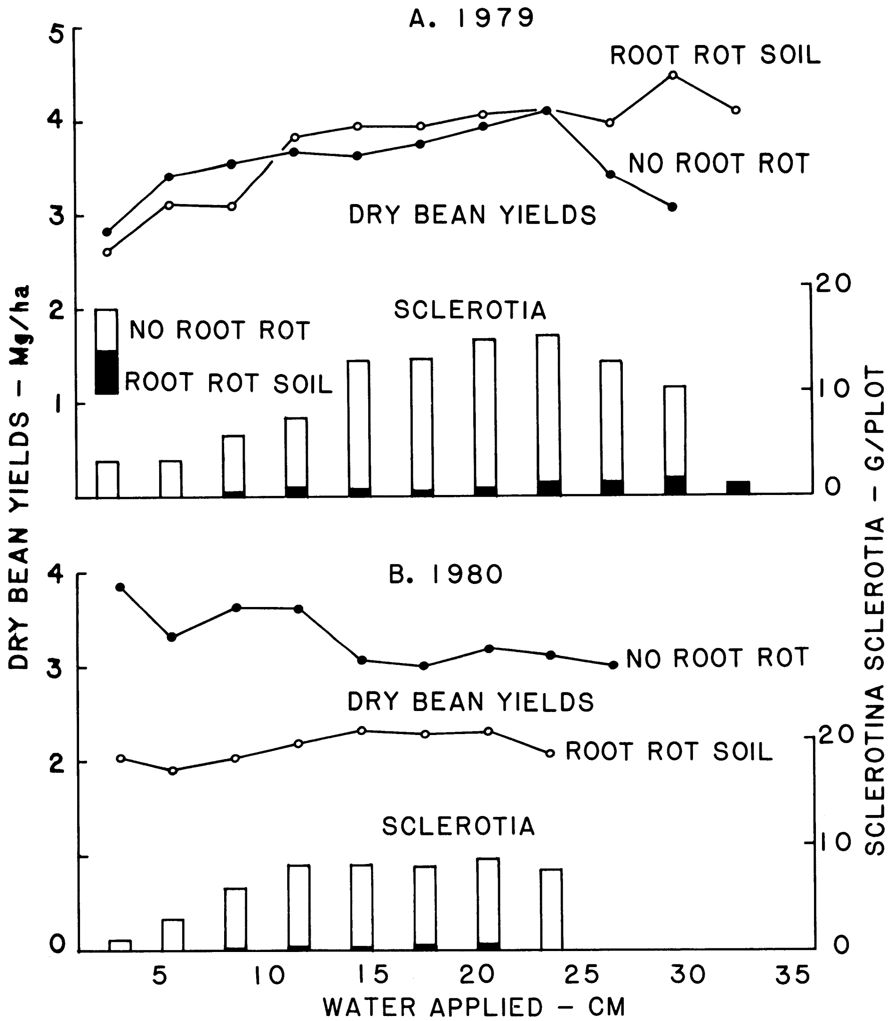

Fig. 2. Dry bean seed yields and *Sclerotinia* sclerotia found in threshed bean samples as affected by irrigation rate and presence or absence of the Fusarium root rot pathogen during **(A)** 1979 and **(B)** 1980. Data are averages of all cultivars.

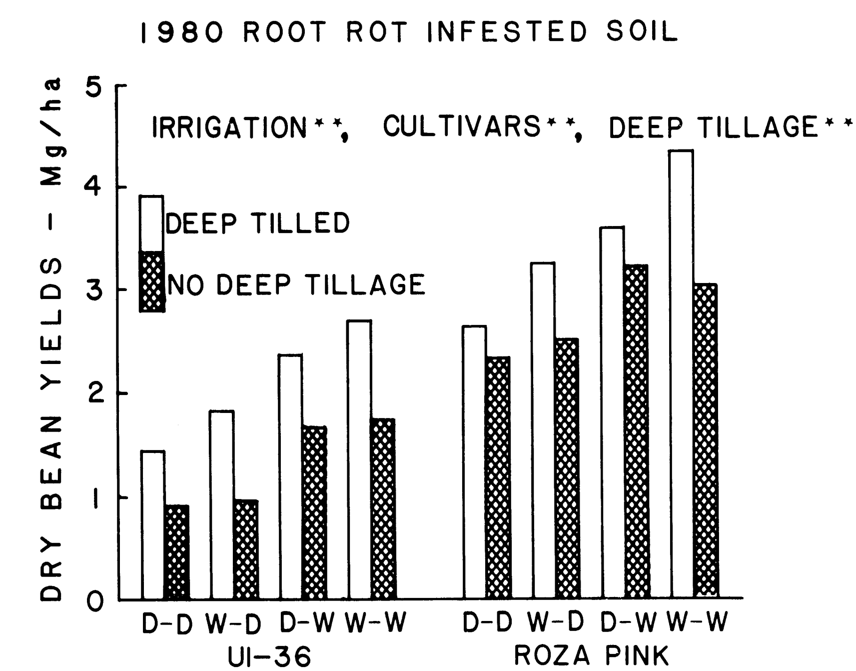

Fig. 3. Effects of irrigation regime, cultivar, and deep tillage on dry bean seed yields from Fusarium root rot-infested soil in 1980. D-D, W-D, D-W, and W-W refer to the precover and postcover irrigation regimes, where D = no irrigation before full cover (alternate irrigations omitted after full cover) and W = irrigated three times before full cover (estimated evapotranspiration replaced every 3–5 days after full cover). ** = Treatments significantly different at $P = 0.01$.

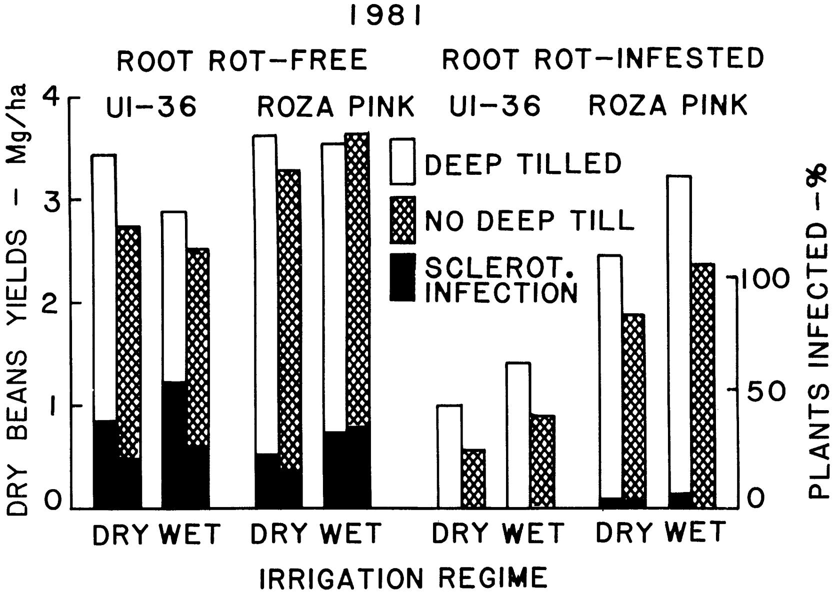

Fig. 4. Effects of irrigation regime, cultivar, and deep tillage on dry bean seed yields and *Sclerotinia* infection on Fusarium root rot-infested and noninfested soil in 1981. Wet = estimated evapotranspiration replaced every 3–5 days after full cover. Dry = alternate irrigations omitted.

presence or absence of Fusarium root rot in the field (Fig. 4). This was true even at similar yields from *Fusarium*-infested and noninfested fields. Incidence of Sclerotinia wilt was negligible in the *Fusarium*-infested field, although there was some infection in plots where treatments encouraged foliage growth, i.e., deep tillage, frequent irrigation, and *Fusarium* resistance (Roza Pink). Observations by the second author in many bean fields indicate that the relationship of soil infestations by *F. solani* f. sp. *phaseoli* to incidence of Sclerotinia wilt is unusual, except when Fusarium root rot reduces foliage development. The *Fusarium*-infested fields used in this study had been monocropped to beans for more than 20 yr and possibly had developed a microbiological or physical status unfavorable to Sclerotinia wilt.

In the field not infested by *Fusarium*, all plots contained appreciable Sclerotinia wilt, and the incidence also was generally increased by treatments that increased foliage density (frequent irrigation and deep tillage). It is probable that yield responses to these treatments were masked by *Sclerotinia*, and we may have obtained higher yields with frequent irrigation and deep tillage if plants had not become infected with *Sclerotinia*.

These results support our previous conclusions (6) that in fields not infested by *F. solani* f. sp. *phaseoli*, with soil of the type used in this study, irrigation can be reduced to about one-half the estimated Et without serious water-stress injury and that there is little benefit from deep tillage. When soil is infested with *F. solani* f. sp. *phaseoli*, yields can be maintained by the combination of adequate irrigation, deep tillage, and use of a *Fusarium*-resistant cultivar. Irrigation and soil management to control both Fusarium root rot and Sclerotinia wilt remain to be refined. Sclerotinia wilt can be reduced by less frequent or reduced irrigation, thus providing a less humid canopy environment.

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