Effect on potato cultivars (*Solanum tuberosum L. cv. Maris Anchor, Maris peer, Pentland Crown, Maris Piper)*

1. The net impact of individual and combined stress on plant growth

Crop: Potato (Solanum tuberosum L. cv. Maris Anchor, Maris peer, Pentland Crown, Maris Piper)
Stress 1: *Globodera rostochiensis and G. pallida*
Stress 2: *Verticillium dahliae*
Stage of plant: Sowing

The table shows the impact of nematode and fungus alone and in combination on yield of and age of potato genotypes.

	Treatment	Plant response to stress Type A parameters*	
		Yield (reduction over control %)	**Age (weeks at which plants died)****
Maris Anchor	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	40.3 ↓	10.5
	Globodera rostochiensis (10 eggs/g soil)	-26.9 ↑	N/A
	Globodera rostochiensis (50 eggs/g soil)	11.94 ↓	N/A
	Globodera rostochiensis (250 eggs/g soil)	28.36 ↓	14.8
	Globodera rostochiensis (1250 eggs/g soil)	58.21 ↓	15.2
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	61.19 ↓	9.8
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	73.13 ↓	8.8
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	73.13 ↓	9.8
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	83.58 ↓	9.2

	Globodera pallida (10 eggs/g soil)	5.97↓	15.2
	Globodera pallida (50 eggs/g soil)	28.36↓	N/A
	Globodera pallida (250 eggs/g soil)	92.54↓	6.8
	Globodera pallida (1250 eggs/g soil)	97.01↓	6
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	46.27↓	10.2
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	59.7↓	9.5
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	79.1↓	8.7
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	94.03↓	8.2
Maris Peer	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	-47.1↑	15.2
	Globodera rostochiensis (10 eggs/g soil)	25↓	13.2
	Globodera rostochiensis (50 eggs/g soil)	14.71↓	N/A
	Globodera rostochiensis (250 eggs/g soil)	91.18↓	7.5
	Globodera rostochiensis (1250 eggs/g soil)	97.06↓	6
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.94↓	N/A
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	58.82↓	11.2

	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	91.18⬇	7.3
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	95.59⬇	6.2
	Globodera pallida (10 eggs/g soil)	-2.94⬆	N/A
	Globodera pallida (50 eggs/g soil)	-4.41⬆	N/A
	Globodera pallida (250 eggs/g soil)	94.12⬇	7
	Globodera pallida (1250 eggs/g soil)	97.06⬇	6.5
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	16.18⬇	14.8
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.47⬇	12.8
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	89.71⬇	7.5
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	97.06⬇	6.5
Pentland Crown	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	-19.8⬆	13.2
	Globodera rostochiensis (10 eggs/g soil)	-7.69⬆	N/A
	Globodera rostochiensis (50 eggs/g soil)	-1.1⬆	N/A
	Globodera rostochiensis (250 eggs/g soil)	26.37⬇	N/A
	Globodera rostochiensis (1250 eggs/g soil)	35.16⬇	N/A
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.19⬇	N/A

	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	40.66↓	N/A
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	40.66↓	N/A
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	50.55↓	14.5
	Globodera pallida (10 eggs/g soil)	-38.5↑	N/A
	Globodera pallida (50 eggs/g soil)	-7.69↑	N/A
	Globodera pallida (250 eggs/g soil)	2.19↓	N/A
	Globodera pallida (1250 eggs/g soil)	36.26↓	N/A
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	10.99↓	N/A
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	39.56↓	N/A
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	31.87↓	N/A
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	45.05↓	14.2
Maris Piper	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	6.25↓	N/A
	Globodera rostochiensis (10 eggs/g soil)	6.25↓	N/A
	Globodera rostochiensis (50 eggs/g soil)	-51↑	N/A
	Globodera rostochiensis (250 eggs/g soil)	14.58↓	N/A

	Globodera rostochiensis (1250 eggs/g soil)	19.79↓	N/A
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	-38.5↑	N/A
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	21.88↓	N/A
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	-34.4↑	N/A
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	39.58↓	N/A
	Globodera pallida (10 eggs/g soil)	-28.1↑	N/A
	Globodera pallida (50 eggs/g soil)	1.04↓	N/A
	Globodera pallida (250 eggs/g soil)	38.54↓	N/A
	Globodera pallida (1250 eggs/g soil)	56.25↓	15.2
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	-33.3↑	N/A
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	33.33↓	N/A
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	23.96↓	N/A
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	48.96↓	N/A

The table shows the impact of nematode and fungus alone and in combination on total water used, dry weight shoot, dry weight root, Shoot/root ratio, dry weight tubers and transpiration ratio in potato plants.

	Treatment	Plant response to stress (reduction over control %) Type A parameters*					Plant response to stress (reduction over control %) Type B parameters*
		Total water used	Dry weight shoot	Dry weight root	Shoot/Root ratio	Dry weight tubers	Transpiration Ratio
Maris Anchor	*Verticillium dahliae (12.5 X 105 propagules/g soil)*	4.8↓	1.1↓	-5.0↑	6.3↓	14.0↓	-3.3↑
	Globodera rostochiensis (250 eggs/g soil)	37.5↓	-3.8↑	-47.5↑	30.3↓	57.2↓	-0.7↑
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (12.5 X 10^5 propagules/g soil) 12 days weeks later (Sequential inoculation)	54.2↓	28.6↓	-10.0↑	36.5↓	83.9↓	-6.9↑
Maris Peer	*Verticillium dahliae (12.5 X 105 propagules/g soil)*	1.4↓	0.9↓	5.7↓	-5.8↑	2.7↓	-1.4↑
	Globodera rostochiensis (250 eggs/g soil)	47.2↓	25.5↓	-18.9↑	37.2↓	80.2↓	10.7↓
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (12.5 X 10^5 propagules/g soil) 12 days weeks later (Sequential inoculation)	61.4↓	46.6↓	7.5↓	42.9↓	92.0↓	1.9↓

Note: *Values presented in the table were calculated using the formula described below.*

$$\text{Reduction over control (\%)} = \frac{(\text{Value}_{\text{Control}} - \text{Value}_{\text{Stress}})}{} \times 100$$

Value $_{Control}$

1) '⬇'- indicates plant parameters affected by stress that lead to high susceptibility (higher the value more the damage).

2) '⬆ '- indicates plant parameters less/not affected by stress leading to improved resistance (higher the value lesser the damage).

'' - For more information on parameters classification, please refer to 'methodology' tab.*

*'**' - Values are presented as it is from the source article without subjecting to the calculation.*

2. The interaction between nematode and fungal pathogen under combined stress at plant interface

The table shows the effect of the fungal pathogen on nematode population and effect of nematode on fungus induced early dying foliage score under combined stress treatment

	Treatment	Treatment Response to combined stress** Type B parameters*	
		Early-dying foliage score	***G. rostochiensis* / *G. pallida* (eggs/g soil)**
Maris Anchor	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	5	N/A
	Globodera rostochiensis (10 eggs/g soil)	0	0.43
	Globodera rostochiensis (50 eggs/g soil)	0.7	0.3
	Globodera rostochiensis (250 eggs/g soil)	2.7	0.77
	Globodera rostochiensis (1250 eggs/g soil)	2.3	0.2
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.37
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.33

	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.13
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.23
	Globodera pallida (10 eggs/g soil)	1.7	31.6
	Globodera pallida (50 eggs/g soil)	0	16.1
	Globodera pallida (250 eggs/g soil)	5	2.67
	Globodera pallida (1250 eggs/g soil)	5	0.73
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	12.6
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	3.8
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	1.63
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.43
	Verticillium dahliae (12.5 X 105 propagules/g soil)	N/A	N/A
	Globodera rostochiensis (250 eggs/g soil)	N/A	N/A
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (12.5 X 10^5 propagules/g soil) 12 days weeks later (Sequential inoculation)	N/A	N/A
Maris Peer	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	2.3	N/A

	Globodera rostochiensis (10 eggs/g soil)	1.7	93.8
	Globodera rostochiensis (50 eggs/g soil)	0.7	4.53
	Globodera rostochiensis (250 eggs/g soil)	5	1.73
	Globodera rostochiensis (1250 eggs/g soil)	5	0.83
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	3	20
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	16.3
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	1
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	1.13
	Globodera pallida (10 eggs/g soil)	0.7	41
	Globodera pallida (50 eggs/g soil)	1	25.9
	Globodera pallida (250 eggs/g soil)	5	0.9
	Globodera pallida (1250 eggs/g soil)	5	0.53
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	44.1
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	4.3	11.2
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	1.6

	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	5	0.73
	Verticillium dahliae (12.5 X 105 propagules/g soil)	N/A	N/A
	Globodera rostochiensis (250 eggs/g soil)	N/A	N/A
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (12.5 X 10^5 propagules/g soil) 12 days weeks later (Sequential inoculation)	N/A	N/A
Pentland Crown	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	1.7	N/A
	Globodera rostochiensis (10 eggs/g soil)	1	98.5
	Globodera rostochiensis (50 eggs/g soil)	0	13.4
	Globodera rostochiensis (250 eggs/g soil)	0.3	5.17
	Globodera rostochiensis (1250 eggs/g soil)	0.3	1.5
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	0.7	85.5
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.7	20.9
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1	4.33
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.3	1.47
	Globodera pallida (10 eggs/g soil)	0.3	57.7
	Globodera pallida (50 eggs/g soil)	1.3	46.6
	Globodera pallida (250 eggs/g soil)	0.3	4

	Globodera pallida (1250 eggs/g soil)	1	2.2
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	0.3	40.6
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	0.7	6.83
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.3	5.93
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.3	0.67
Maris Piper	*Verticillium dahliae (3.5 X 105 propagules/g soil)*	2	N/A
	Globodera rostochiensis (10 eggs/g soil)	0.7	1.27
	Globodera rostochiensis (50 eggs/g soil)	0.3	0.3
	Globodera rostochiensis (250 eggs/g soil)	0.7	0.7
	Globodera rostochiensis (1250 eggs/g soil)	0.3	0.23
	Globodera rostochiensis (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	0	3.07
	Globodera rostochiensis (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.7	0.63
	Globodera rostochiensis (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.7	0.2
	Globodera rostochiensis (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2	0.37
	Globodera pallida (10 eggs/g soil)	0.7	22.1

	Globodera pallida (50 eggs/g soil)	0.3	9.93
	Globodera pallida (250 eggs/g soil)	0	2.3
	Globodera pallida (1250 eggs/g soil)	2.3	1.23
	Globodera pallida (10 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.3	50.9
	Globodera pallida (50 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	2.7	14.7
	Globodera pallida (250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.3	6
	Globodera pallida (1250 eggs/g soil) + Verticillium dahliae (3.5 X 105 propagules/g soil) 5 weeks later (Sequential inoculation)	1.7	0.67

For raw data – Click here (.xlsx file)

Reference - Evans K (1987) The interactions of potato cyst nematodes and Verticillium dahliae on early and maincrop potato cultivars. Ann. appl. Biol. 110: 329-339

Note:

'**' - *Values are presented as it is from the source article without subjecting to the calculation.*

'' - For more information on parameter classification, please refer to the 'methodology' tab.*

Inference From the study: Evans K (1987) studied the interaction of *Globodera rostochiensis, Globodera pallida* and *Verticillium dahliae* in four potato cultivar Maris Anchor, Maris peer, Pentland Crown, and Maris Piper . Pathogens were inoculated singly and sequentially at different inoculum levels. Plants were then analysed for their yield and age at which plants died post-infection, total water used dry weight shoot, dry weight root, Shoot/root ratio, dry weight tubers, and transpiration. Sequential inoculations of the *Globodera rostochiensis* along with fungus resulted in an additive decrease in yield, shoot/root ratio, and dry weight of tubers. The transpiration ratio was high under combined stress treatment. Fungus induced early dying foliage score was high in sequential inoculation. **Thus, this pathogen combination acts synergistically to reduce plant growth and cause a severe disease complex under combined stress treatment in all potato cultivars.**